FOURTH EDITION 199?

BEST AVAILABLE COPY

REINFORCEMENT ANCHORAGES AND SPLICES

CRSI

CONCRETE REINFORCING STEEL INSTITUTE

FOUNDED 1924

ASTM STANDARD REINFORCING BARS

BAR SIZE DESIGNATION	NOMINAL DIMENSIONS		
	AREA ($in.^2$)	WEIGHT (lb/ft)	DIAMETER (in.)
#3	0.11	0.376	0.375
#4	0.20	0.668	0.500
#5	0.31	1.043	0.625
#6	0.44	1.502	0.750
#7	0.60	2.044	0.875
#8	0.79	2.670	1.000
#9	1.00	3.400	1.128
#10	1.27	4.303	1.270
#11	1.56	5.313	1.410
#14	2.25	7.65	1.693
#18	4.00	13.60	2.257

The current A615 specification covers bar sizes #14 and #18 in Grade 60, and bar sizes #11, #14 and #18 in Grade 75. The current A706 specification also covers bar sizes #14 and #18. Bar sizes #14 and #18 are not included in the A616 and A617 specifications.

REINFORCEMENT ANCHORAGES AND SPLICES

FOURTH EDITION 1997

Prepared under the Direction of the CRSI Engineering Practice Committee
by the Committee on Reinforcement Anchorages and Splices

COMMITTEE ROSTER

John R. Deubert, Chairman	Fox-Howlett Industrie:
Larry Andresen	Bar-Lock Coupler System:
Larry G. Alcorn	BarSplice Products, Inc
Roger J. Bambach	J. M. Ahle Co., Inc
Steve Brown	Richmond Screw Anchor Co
Calvin G. Billet	Erico, Inc
Larry Campbell	Rebar Services & Supply Co
Alvin C. Ericson	Consultan
Gustav G. Erlemann	Consultant
Donald G. Fowler	Meadow Steel Product:
Paul S. Fredrickson	Erico, Inc
Andy Gaines	Richmond Screw Anchor Co
David F. Horton	Barker Steel Company, Inc
Glenn Gross	South Coast Steel Service, Inc
Mark K. Kaler	American Highway Technolog
Harry B. Lancelot III	Richmond Screw Anchor Co
Antonio S. Limbardo	Engineered Devices Corporatioı
Christopher T. Limbardo	Engineered Devices Corporatior
Donald L. Lindau	Meadow Steel Product:
Donald F. Meinheit	Wiss, Janney, Elstner Associate
Robert Minieri	Universal Form Clam
Peter Meza	P. M. Consultin
Alan Monnin	Dayton Superior Corporatioı
Heinz Nierlich	Dywidag Systems International, USA, Inc
John R. Paine, Jr.	Dayton Superior Corporatioı
Guy Parker	Steel Engineers, Inc
Conrad Paulson	Wiss, Janney, Elstner Assoc
Edward D. Ricker	Erico, Inc
Roy H. Reiterman	Wire Reinforcement Institut
Robert G. Smith	Erico, Inc
Ronald J. Watson	BarSplice Products, Inc
Anthony L. Felder, Secretary	Concrete Reinforcing Steel Institut

FOREWORD

Design and layout of anchorages and splices involves a unique combination of art and science in any complete reinforced concrete structural design. Properly designed splices are a key element in any well-executed design. End anchorage for bars in principal framing elements terminating at edges of a structure often must be accomplished in joints where space is limited and fit is complicated by crossing bars in other planes. Practical considerations of cost, construction time, and feasibility under normal construction conditions are of equal importance in meeting Code requirements. The purpose of this publication is to present the Architect/Engineer with a variety of design options from the most widely-accepted practices in anchoring and splicing reinforcement.

The Institute believes that adherence to the recommendations contained in this publication will assure performance in accordance with the design requirements of the Architect/Engineer and result in substantial economies for all concerned.

The requirements of ACI 318-95 [318M-95] affecting anchorages and splices have been referenced in this publication. Development and lap splice tables for reinforcing bars and welded wire fabric, per the AASHTO Bridge Specifications and the AASHTO LRFD Bridge Design Specifications, have also been included.

The requirements for splicing and anchorage in "Code for Concr Reactor Vessels and Containments (ACI 359-89)," Chapter 21 (Spe Provisions for Seismic Design) and in "Code Requirements for Nucl Safety Related Concrete Structures (ACI 349-90)" are not covered in publication.

The recommendations and examples in this publication concern the selection and use of reinforcing materials, anchorages, methods splicing, and mechanical splices are merely illustrative. In any design p ject, the judgment of an experienced Architect/Engineer should be use to the best way of achieving specific design requirements.

Proprietary mechanical splices are shown for information purp only. CRSI does not perform inspection or certification of quality no any way guarantee performance of proprietary mechanical splices nor ommend one manufacturer's splice over another's. Those shown h been used in actual structures in the U.S. Performance data are avail only from the manufacturers. The Architect/Engineer should determ whether particular mechanical splices possess the special proper required for the intended purposes and, if necessary, are acceptabl local code or building authorities.

CONCRETE REINFORCING STEEL INSTITUTE
933 North Plum Grove Road Schaumburg, Illinois 60173-4758

REINFORCEMENT ANCHORAGES AND SPLICES
TABLE OF CONTENTS

1.1 GENERAL

The analysis of reinforced concrete structures subjected to various external loads and forces is generally predicated upon the assumption that all the separate elements of reinforced concrete behave as a unit. Due to practical limitations, the actual structure must be built piece by piece or story-by-story. Nevertheless, one of the principal elements of the art of design is to produce this monolithic behavior of the finished structure. Properly located construction joints in the concrete will ensure transmission of the compressive force in excess of that carried by concrete and all tensile forces required to cross the construction joint must be carried by the reinforcement. Just as it is physically impossible to cast all concrete in one monolithic, continuous operation, it is impossible to provide full length continuous reinforcement throughout any sizeable structure. Splices of reinforcement are unavoidable. Properly designed splices are a key element in any well executed design. Many splice situations are unique and require "custom-made" engineering solutions.

1.2 REINFORCING BARS

Since anchorage and splices of reinforcing bars ("rebars") are essential to the monolithic behavior of the finished structure, the Architect/Engineer should be familiar with the practical limitations of placing (installing) reinforcing bars. Practical limitations on the length of rebars occur during manufacture, fabrication, transportation to jobsite, and on the jobsite. Most steel mills roll rebars to a standard stock length of 60 ft [18.3 m]* for all except the smallest and largest sizes. Longer lengths require special rolling arrangements. The absolute maximum length possible varies greatly from mill to mill.

Fabricating shops using stock on hand are normally limited to bar lengths of 60 ft [18.3 m]. Bending equipment and its location in the shop may also impose limitations on the length of bent bars.

When shipping bars by truck, economic, legal, and physical limitations as to bar length, and width (Fig. 1) of bent bars must be considered. Maximum length, in addition to mill and fabricating shop limits, is determined by the number of bars involved, the route from the fabricating shop to the jobsite, the available trucking equipment and construction limitations at the jobsite. Practical construction limitations on bar length must also be considered. Except for slabs on grade, long lengths of horizontal bars projecting beyond required construction joints are generally undesirable. Vertical members limit feasible bar lengths most severely. In multistory construction, column bars are usually one-story or two-story in height. For designs with larger size bars in columns requiring staggered mechanical splices or butt-welded splices, use of two-story or three-story height column verticals is usually recommended. Only larger s vertical bars have sufficient stiffness for use in free-standi two-story lengths. Tall columns or piers, as required some bridges, can utilize longer vertical bars where for work serves to brace the bars, but it is usually best to s within stock length limitations. For practical economy, m structures should be designed to utilize rebars within th limits and the stock length of 60 ft [18.3 m].

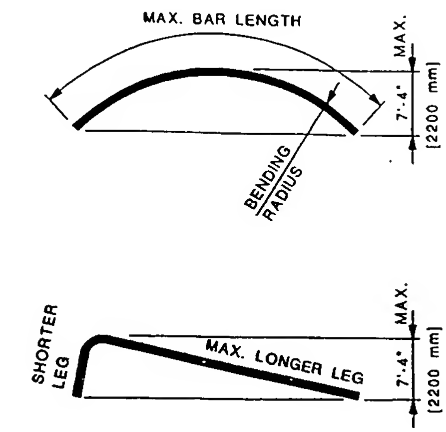


Fig. 1—Maximum Dimension—Bundles of Bent Bars for Truck Delivery (7 ft-4 in. is equivalent to 2200 mm)

1.3 WELDED WIRE FABRIC

Welded wire fabric (WWF) is manufactured in sheets : rolls. Wire sizes of W1.4 and smaller are usually manu tured only in rolls. Maximum sheet and roll sizes v according to the manufacturer's equipment. Shipp restrictions should also be considered when choosing fal styles. WWF is available in rolls, generally 5 to 7 ft [150(2100 mm] wide and 150 to 200 ft [46 to 61 m] long, or i ft [2400 mm] wide, 20 ft [6100 mm] long sheets.

Welded wire fabric may be designed as "one-way" fab with primary reinforcing wires in one direction only, : cross-wires serving only as "holding" wires. Or, as it m often the case, the wires in both directions are designe structural reinforcement. In this case, full strength laps anchorages are usually specified on all sides of the fa sheets.

* Metric equivalent of 60 ft. Metric equivalents are prese throughout this publication.

2.1 GENERAL

The ACI Building Code requires for design purposes that reinforcing bar splices be classified as tensile or compressive. If the splice will undergo stress reversal, it will be necessary to determine the magnitude of both tension and compression stresses. Normally, tensile stress will control as tensile requirements are more severe. Tension-controlled splices are further classified as to location and stress level. Separate requirements are provided for tension splices in tension tie members.

Depending upon location and percentage of reinforcement spliced at a single cross section, tension lap splice requirements are defined as Class A or Class B. Corresponding requirements for other types of splices are also defined.

2.2 APPLICATION OF CODE DESIGN REQUIREMENTS

In the application of the ACI Building Code design requirements to a practical design, several areas appear open to various interpretations. The following notes may assist the reader in developing interpretations within their intent:

1. No splice exactly reproduces the behavior of a continuous bar. To ensure against a premature (brittle) splice failure, full mechanical splices* and full welded splices at points of critical tension are required to develop a minimum of 125 percent f_y. Presumably, minimum lap length rules provide the same margin of overload capacity and this factor defines the requirement of "full development."
2. The Code limits bundled bars to four bars to ensure concrete penetration for bond. Include the splice bar, if used, within this limit, which would limit bundles with splice bars to three effective bars. Bundled bars may be offset bent.
3. Splices within bundles may be mechanical splices, double lap spliced, or butt-welded. For mechanical splices or butt-welded splices, devices using thick sleeves or enlarged sections can present practical difficulties to fitting within a tight bundle. Generally, these difficulties can be minimized by staggering the splices. The double lap splice (separate splice bar) requires staggering each bar end one lap length minimum, but does permit use of standard shear cut ends. The splice bar must be included in the bundle size when computing the lap length required.
4. For overall economy, many Architects/Engineers prefer to retain the same column size from footings to roof, reducing vertical reinforcing steel and concrete strengths only, which saves construction time and formwork.
5. The Commentary to ACI 10.9.1** states: "The percentage of reinforcement in columns should usually not exceed 4 percent if the column bars are required to be lap spliced."
6. Where vertical bars in columns are offset bent, reduction in flexural capacity proportional to the reduced effective depth should be considered.
7. #14 and #18 [#43 and #57] bars must be mechanically-spliced or butt-welded; except lap splices are permitted in compression only to #11 [#36] and smaller bars (ACI 12.16.2 and ACI 15.8.2.3). They can be offset bent when used as column verticals.
8. End-bearing mechanical splices (tensile capacity of zero) can be used where the bar is not required for tension. If tension exists in a column at the cross-section where end-bearing mechanical splices are used, a tensile capacity should be provided in each column face equal to twice the maximum computed tension in that column face. If tension exists at the cross-section where an end-bearing mechanical splice is used, unspliced bars running continuously through the cross-section for the full tension development distance should be supplied.
9. The Code does not require that all mechanical splices or butt-welded splices be staggered (ACI 12.15.3) except as required by ACI 12.15.4.1 and ACI 12.15.5. Column butt splices designed for seismic conditions whether mechanically-spliced or welded, in compression or tension, require a minimum stagger of 24 in. [600 mm] (ACI 21.3.2.4). Butt splices of all bars (other than seismic design) can, under some conditions, be made at one point in a story permitting economical preassembly of bars into "column cages."
10. Longest length spiral normally fabricated is approximately 15 ft [4500 mm] in height. Tall piers in bridges and piles for deep foundations may require spirals which exceed 15 ft [4500 mm] in height. When these conditions occur, spirals are usually spliced together in the field.

*Defined in this publication as a mechanical splice capable of both tension and compression.

**Reference to the ACI Building Code, ACI 318-95, is given as "ACI" followed by the number of the section.

2.3 CRSI RECOMMENDATIONS TO ARCHITECTS/ENGINEERS FOR SPLICES

1. Only the Architect/Engineer can design the splices. The design drawings, notes, and project specifications should clearly show or describe all splice locations, lap splice lengths, and types of splices permitted or required (ACI 1.2.1).
2. Follow recommended requirements for lap splice lengths as shown in this publication.
3. For #14 and #18 [#43 and #57] bars, use mechanical splices only; except lap splices are permitted in compression only to #11 [#36] and smaller bars.
4. When splices are required only for compression, and lap splices are undesirable, use end-bearing mechanical splices for economy.
5. Bundles of #14 and #18 [#43 and #57] bars are not permitted for beams under the ACI Building Code, and they are not recommended for general use in buildings. In bridges, 2-bar bundles of #14 or #18 [#43 and #57] may be used in beams or columns.
6. Avoid manual arc welding in the field wherever possible. Consider mechanical splices as an alternate.
7. Where arc welded splices are used, the following are required:
   (a) ASTM A706 low-alloy steel rebars should be specified
   (b) Welding of reinforcing bars should conform to requirements of ANSI/AWS D1.4-92 "Structural Welding Code—Reinforcing Steel"
8. Never permit field welding of crossing bars ("tack" welding, "spot" welding). Tie wire will suffice without harm to the bars.
9. Except where job conditions make it impossible, it is considered good practice to stagger splices of any type. Practical requirements, such as enlarged size of mechanical splices or equipment, make a minimum stagger length preferable. Lap splices, if staggered, can usually be made shorter.

Methods available for splicing reinforcing bars are: lap splices, mechanical splices and welded splices.

3.1 LAP SPLICES

General

This is the predominant method of splicing. Bars may be spaced or in contact. For bar-to-bar splices, contact splices are preferred for the practical reason that, wired together, they are more easily secured against displacement during concrete casting. Non-contact lap-spliced bars should not be spaced too widely apart, permitting a zigzag crack between bars. Spacing of bars in non-contact lap splices should not exceed one-fifth the lap length nor 6 in. [150 mm]. See Fig. 2.

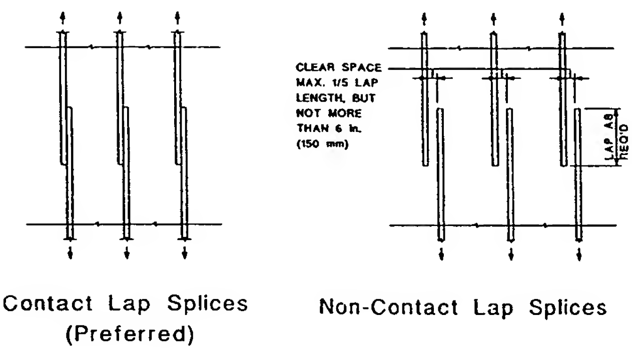


Fig. 2—Contact and Non-Contact Lap Splices

Lap-Splice Connector Systems

Lap splice connector systems, as the term is used in this publication, describe proprietary prefabricated plastic or metal boxes or strips of foam containing prefabricated anchorage and lap splice reinforcement. Rebar end hooks are made to specified dimensions and have one end factory bent and inserted into a two-piece box of plastic or metal or embedded in a foam plank. The assembly is attached to the formwork at a construction joint, with the exposed end hook of each bar projecting back inside the form where it will be embedded in concrete of the initial placement. After the forms are stripped, the encased or boxed lap splice reinforcement is exposed. This is done either by removing the form side of the plastic or metal box or extracting the foam. Then the pre-bent lap splice bars are field straightened with a pipe and/or hickey. See Fig. 3.

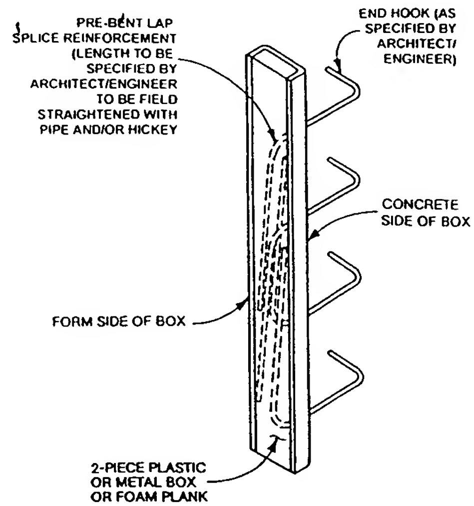


Fig. 3—Lap-Splice Connector

The ACI Building Code permits field bending of partially embedded reinforcing bars when shown on design drawings or permitted by the Architect/Engineer. Therefore, engineering approval should be obtained prior to the use of these systems.* These systems are and have been used in actual structures in the U. S. with rebar as large as a #6 [#19]. Some manufacturers limit the bar sizes to #3, #4, and #5 [#10, #13, and #16] only. Available technical literature suggests that successfully field rebending Grade 60 [420] rebar as large as a #6 [#19] depends significantly on the specific rebar's rebendability characteristics, the tightness of the initial bar bend, the rebending axis, the bar temperature, and the straightening impact. The rebendable potential of rebar is affected by deformation pattern, heat treatment, physical properties, and chemical composition. These factors can be expected to vary between mill sources and heats. Rebendability is not part of the current ASTM specifications for reinforcing bars.

*For more information, see Appendix C.

Bundled Bar Splices

Special rules are provided for splices of bundled bars in ACI 12.14.2.2. Since individual bar splices within a bundle should not overlap, lap splices must be staggered at least equal to the length of the required lap splice. See Fig. 4. If a full mechanical splice or a full butt-welded splice is used, a staggered location of the splice point is recommended to avoid bunching all mechanical splices or welded splices at one point. If end-bearing mechanical splices are used, and full tensile capacity of unspliced bars at each splice point is desired, the length of stagger must be at least equal to the required tension development length of the bars. If end-bearing mechanical splices are used for compression only, a staggered location of the splice point, usually 2 or 3 ft [600 or 900 mm], is recommended as an erection convenience. Compression capacity for this arrangement is taken as 100 percent. If the stagger is made equal to the tension lap splice length required by the ACI Building Code, this arrangement is assumed to provide a 50 percent tensile capacity for a 2-bar bundle, a 66 percent capacity for a 3bar bundle, and a 75 percent capacity for a 4-bar bundle.

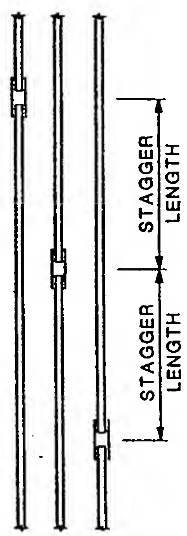


Fig. 4—Staggering of Bundled Bar Splices

Seismic Joints

The provisions of Chapter 1 through 18 of the ACI 318/318M Code apply for seismic conditions except as modified by the provisions of Chapter 21. Chapter 21 provides modified requirements for tension development of straight bars and standard hook development within a joint. Therefore, tables are presented herein for tension development and standard hook development within seismic joints. Note that ACI 318/318M, Section 21.3.2.3, does not allow lapping of rebars in a joint. Note also that compression development and compression lap splices are applicable for both non-seismic and seismic conditions.

The AASHTO Bridge Specifications do not have special requirements for seismic conditions so development and lap splice lengths are the same for non-seismic and seismic conditions.

Development and Lap Splice Length Tables

The following 35 tables of development and lap splice lengths cover the following:

1. Inch-pound and metric units.
2. Reinforcing bars, deformed wire, deformed welded wire fabric and plain welded wire fabric.
3. Tension development, tension lap splice, hook development, compression development and compression lap splice lengths.
4. ACI 318 Building Code and the AASHTO Standard Specifications for Highway Bridges.
5. Uncoated and epoxy-coated steel.
6. Non-seismic and seismic joint conditions.

In order to assist the reader in quickly locating the specific table of interest, refer to the chart on the following page:

LOCATION CHART FOR DEVELOPMENT AND LAP SPLICE TABLES

Table	Units		Steel Reinforcement				Length					Code		Coating		Condition	
	In -Lb	Metric	Bars	Deformed Wire	Deformed WWF	Plain WWF	Tension Develop.	Tension Lap Splice	Hook Develop.	Comp. Develop.	Comp. Lap Splice	ACI	AASHTO	Uncoated	Epoxy-Coated	Non-Seismic	Seismic Joints
1	X		X				X	X				X		X		X	
2	X		X				X	X				X			X	X	
3	X		X				X	X					X	X		X	X
4	X		X				X	X					X		X	X	X
5[1]	X		X				X	X				X		X	X	X	
6[2]	X		X				X	X				X		X	X	X	
7	X		X				X					X		X			X
8	X		X				X					X			X		X
9	X		X						X			X	X	X		X	
10	X		X						X			X	X		X	X	
11	X		X						X			X		X			X
12	X		X						X			X			X		X
13	X		X							X	X		X	X	X	X	
14[3]	X			X			X	X				X		X		X	
15[3]	X				X		X					X		X			X
16	X							X				X		X			X
17	X						X							X		X	
18		X					X					X		X		X	
19		X					X								X		X
20		X	X				X						X	X		X	
21		X	X				X	X					X		X	X	
22[1]		X	X				X	X				X		X	X	X	
23[2]		X	X				X	X				X		X	X	X	
24		X	X				X					X		X			X
25		X	X				X								X		
26		X	X						X			X	X	X		X	
27		X	X						X				X		X		
28		X	X						X			X		X			X
29		X	X						X			X			X		X
30		X	X							X	X	X	X	X	X	X	X
31[3]		X		X			X	X				X		X		X	X
32[3]		X			X		X					X		X		X	X
33[3]		X			X			X				X		X		X	X
34[3]		X				X	X	X				X		X		X	X
35[4]	X	X	X				X	X				X		X	X	X	

[1] Walls and slabs, 3000 psi [21 MPa] concrete.
[2] Walls and slabs, 4000 psi [28 MPa] concrete.
[3] 4000 psi [28MPa] concrete.
[4] Bar multiples.

TABLE 1—TENSION DEVELOPMENT AND LAP SPLICE LENGTHS FOR UNCOATED BARS (ACI 318, Inch-Pound Values)

Bar Size	Lap Class	Lengths (in.) per Concrete Strength (psi)											
		3000 psi				4000 psi				5000 psi			
		Top Bars		Other Bars		Top Bars		Other Bars		Top Bars		Other Bars	
		Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2
#3	A	22	32	17	25	19	28	15	22	17	25	13	19
	B	28	42	22	32	24	36	19	28	22	33	17	25
#4	A	29	43	22	33	25	37	19	29	22	33	17	26
	B	37	56	29	43	32	48	25	37	29	43	22	33
#5	A	36	54	28	41	31	47	24	36	28	42	22	32
	B	47	70	36	54	40	60	31	47	36	54	28	42
#6	A	43	64	33	50	37	56	29	43	33	50	26	38
	B	56	84	43	64	48	72	37	56	43	65	33	50
#7	A	63	94	48	72	54	81	42	63	49	73	37	56
	B	81	122	63	94	70	106	54	81	63	94	49	73
#8	A	72	107	55	82	62	93	48	71	55	83	43	64
	B	93	139	72	107	80	121	62	93	72	108	55	83
#9	A	81	121	62	93	70	105	54	81	63	94	48	72
	B	105	157	81	121	91	136	70	105	81	122	63	94
#10	A	91	136	70	105	79	118	61	91	70	105	54	81
	B	118	177	91	136	102	153	79	118	91	137	70	105
#11	A	101	151	78	116	87	131	67	101	78	117	60	90
	B	131	196	101	151	113	170	87	131	101	152	78	117
#14	N/A	121	181	93	139	105	157	81	121	94	140	72	108
#18	N/A	161	241	124	186	139	209	107	161	125	187	96	144

Notes:

1. Tabulated values are based on Grade 60 reinforcing bars and normal weight concrete. Lengths are in inches.
2. Tension development lengths and tension lap splice lengths are calculated per ACI 318-95, Sections 12.2.2 and 12.15, respectively. Tabulated values for beams or columns are based on transverse reinforcement and concrete cover meeting minimum Code requirements.
3. Cases 1 and 2, which depend on the type of structural element, concrete cover, and the center-to-center spacing of the bars, are defined as:

Beams or Columns:	Case 1.	Cover at least 1.0 d_b **and** c.-c. spacing at least 2.0 d_b
	Case 2:	Cover less than 1.0 d_b **or** c.-c. spacing less than 2.0 d_b
All Others:	Case 1:	Cover at least 1.0 d_b **and** c.-c. spacing at least 3.0 d_b
	Case 2.	Cover less than 1.0 d_b **or** c.-c. spacing less than 3.0 d_b

4. Lap splice lengths are multiples of tension development lengths; Class A = 1.0 ℓ_d and Class B = 1.3 ℓ_d (ACI 318-95, Section 12.15.1).
5. ACI 318-95 does not allow tension lap splices of #14 or #18 bars. The tabulated values for those bar sizes are the tension development lengths.
6. Top bars are horizontal bars with more than 12 in. of concrete cast below the bars.
7. For lightweight aggregate concrete, multiply the tabulated values by 1.3.

TABLE 1 (CONT.)—TENSION DEVELOPMENT AND LAP SPLICE LENGTHS FOR UNCOATED BARS (ACI 318, Inch-Pound Values)

Bar Size	Lap Class	Lengths (in.) per Concrete Strength (psi)											
		6000 psi				7000 psi				8000 psi			
		Top Bars		Other Bars		Top Bars		Other Bars		Top Bars		Other Bars	
		Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2
#3	A	15	23	12	18	14	21	12	16	13	20	12	15
	B	20	30	16	23	18	28	16	21	17	26	16	20
#4	A	20	31	16	24	19	28	15	22	18	26	14	20
	B	26	40	20	31	25	37	19	28	23	34	18	26
#5	A	25	38	20	29	24	35	18	27	22	33	17	25
	B	33	49	25	38	31	46	24	35	29	43	22	33
#6	A	31	46	24	35	28	42	22	33	26	40	20	30
	B	40	59	31	46	37	55	28	42	34	51	26	40
#7	A	44	66	34	51	41	61	32	47	38	58	30	44
	B	58	86	44	66	53	80	41	61	50	75	38	58
#8	A	51	76	39	58	47	70	36	54	44	66	34	51
	B	66	98	51	76	61	91	47	70	57	85	44	66
#9	A	57	85	44	66	53	79	41	61	49	74	38	57
	B	74	111	57	85	69	103	53	79	64	96	49	74
#10	A	64	96	49	74	59	89	46	69	56	83	43	64
	B	83	125	64	96	77	116	59	89	72	108	56	83
#11	A	71	107	55	82	66	99	51	76	62	93	48	71
	B	93	139	71	107	86	128	66	99	80	120	62	93
#14	N/A	86	128	66	99	79	119	61	91	74	111	57	85
#18	N/A	114	171	88	131	106	158	81	122	99	148	76	114

Notes:

1. Tabulated values are based on Grade 60 reinforcing bars and normal weight concrete. Lengths are in inches.
2. Tension development lengths and tension lap splice lengths are calculated per ACI 318-95, Sections 12.2.2 and 12.15, respectively. Tabulated values for beams or columns are based on transverse reinforcement and concrete cover meeting minimum Code requirements.
3. Cases 1 and 2, which depend on the type of structural element, concrete cover, and the center-to-center spacing of the bars, are defined as:

Beams or Columns:	Case 1:	Cover at least 1.0 d_b **and** c.-c. spacing at least 2.0 d_b
	Case 2:	Cover less than 1.0 d_b **or** c.-c. spacing less than 2.0 d_b
All Others:	Case 1:	Cover at least 1.0 d_b **and** c.-c. spacing at least 3.0 d_b
	Case 2:	Cover less than 1.0 d_b **or** c.-c. spacing less than 3.0 d_b

4. Lap splice lengths are multiples of tension development lengths; Class A = 1.0 ℓ_d and Class B = 1.3 ℓ_d (ACI 318-95, Section 12.15.1).
5. ACI 318-95 does not allow tension lap splices of #14 or #18 bars. The tabulated values for those bar sizes are the tension development lengths.
6. Top bars are horizontal bars with more than 12 in. of concrete cast below the bars.
7. For lightweight aggregate concrete, multiply the tabulated values by 1.3.

TABLE 2—TENSION DEVELOPMENT AND LAP SPLICE LENGTHS FOR EPOXY-COATED BARS (ACI 318, Inch-Pound Values)

Bar Size	Lap Class	Lengths (in.) per Concrete Strength (psi)											
		3000 psi				4000 psi				5000 psi			
		Top Bars		Other Bars		Top Bars		Other Bars		Top Bars		Other Bars	
		Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2
#3	A	28	42	25	37	24	37	22	32	22	33	19	29
	B	37	55	32	48	32	47	28	42	28	42	25	38
#4	A	38	56	33	50	33	49	29	43	29	44	26	38
	B	49	73	43	64	42	63	37	56	38	57	33	50
#5	A	47	70	41	62	41	61	36	54	36	54	32	48
	B	61	91	54	80	53	79	47	70	47	71	42	62
#6	A	56	84	50	74	49	73	43	64	44	65	38	58
	B	73	109	64	96	63	95	56	84	57	85	50	75
#7	A	82	123	72	108	71	106	63	94	63	95	56	84
	B	106	159	94	140	92	138	81	122	82	123	73	109
#8	A	93	140	82	124	81	121	71	107	72	108	64	96
	B	121	182	107	161	105	158	93	139	94	141	83	124
#9	A	105	158	93	139	91	137	81	121	82	122	72	108
	B	137	205	121	181	119	178	105	157	106	159	94	140
#10	A	119	178	105	157	103	154	91	136	92	138	81	122
	B	154	231	136	204	133	200	118	177	119	179	105	158
#11	A	132	197	116	174	114	171	101	151	102	153	90	135
	B	171	256	151	226	148	222	131	196	133	199	117	175
#14	N/A	158	237	139	209	137	205	121	181	122	183	108	162
#18	N/A	210	316	186	278	182	273	161	241	163	244	144	216

Notes:

1. Tabulated values are based on Grade 60 reinforcing bars and normal weight concrete. Lengths are in inches.
2. Tension development lengths and tension lap splice lengths are calculated per ACI 318-95, Sections 12.2.2 and 12.15, respectively. Tabulated values for beams or columns are based on transverse reinforcement and concrete cover meeting minimum Code requirements.
3. Cases 1 and 2, which depend on the type of structural element, concrete cover, and the center-to-center spacing of the bars, are defined as:

Beams or Columns:	Case 1:	Cover at least 1.0 d_b **and** c.-c. spacing at least 2.0 d_b
	Case 2:	Cover less than 1.0 d_b **or** c.-c. spacing less than 2.0 d_b
All Others:	Case 1:	Cover at least 1.0 d_b **and** c.-c. spacing at least 3.0 d_b
	Case 2:	Cover less than 1.0 d_b **or** c.-c. spacing less than 3.0 d_b

4. Lap splice lengths are multiples of tension development lengths; Class A = 1.0 ℓ_d and Class B = 1.3 ℓ_d (ACI 318-95, Section 12.15.1).
5. ACI 318-95 does not allow tension lap splices of #14 or #18 bars. The tabulated values for those bar sizes are the tension development lengths.
6. Top bars are horizontal bars with more than 12 in. of concrete cast below the bars.
7. For lightweight aggregate concrete, multiply the tabulated values by 1.3.
8. For epoxy-coated bars, if the bar c.-c. spacing is at least 7.0 d_b and the concrete cover is at least 3.0 d_b, then Case 1 lengths may be multiplied by 0.918 (for top bars) or 0.8 (for other bars).

TABLE 2 (CONT.)—TENSION DEVELOPMENT AND LAP SPLICE LENGTHS FOR EPOXY-COATED BARS (ACI 318, Inch-Pound Values)

Bar Size	Lap Class	Lengths (in.) per Concrete Strength (psi)											
		6000 psi				7000 psi				8000 psi			
		Top Bars		Other Bars		Top Bars		Other Bars		Top Bars		Other Bars	
		Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2
#3	A	20	30	18	26	19	28	16	25	17	26	15	23
	B	26	39	23	34	24	36	21	32	23	34	20	30
#4	A	27	40	24	35	25	37	22	33	23	35	20	30
	B	35	52	31	46	32	48	28	42	30	45	26	40
#5	A	33	50	29	44	31	46	27	41	29	43	25	38
	B	43	64	38	57	40	60	35	53	37	56	33	49
#6	A	40	60	35	53	37	55	33	49	35	52	30	46
	B	52	77	46	68	48	72	42	63	45	67	40	59
#7	A	58	87	51	77	54	80	47	71	50	75	44	66
	B	75	113	66	99	70	104	61	92	65	98	58	86
#8	A	66	99	58	87	61	92	54	81	57	86	51	76
	B	86	129	76	114	80	119	70	105	74	111	66	98
#9	A	75	112	66	99	69	103	61	91	65	97	57	85
	B	97	145	85	128	90	134	79	119	84	126	74	111
#10	A	84	126	74	111	78	116	69	103	73	109	64	96
	B	109	163	96	144	101	151	89	133	94	142	83	125
#11	A	93	140	82	123	86	129	76	114	81	121	71	107
	B	121	181	107	160	112	168	99	148	105	157	93	139
#14	N/A	112	168	99	148	103	155	91	137	97	145	85	128
#18	N/A	149	223	131	197	138	207	122	182	129	193	114	171

Notes:

1. Tabulated values are based on Grade 60 reinforcing bars and normal weight concrete. Lengths are in inches.
2. Tension development lengths and tension lap splice lengths are calculated per ACI 318-95, Sections 12.2.2 and 12.15, respectively. Tabulated values for beams or columns are based on transverse reinforcement and concrete cover meeting minimum Code requirements.
3. Cases 1 and 2, which depend on the type of structural element, concrete cover, and the center-to-center spacing of the bars, are defined as:

Beams or Columns:	Case 1:	Cover at least 1.0 d_b and c.-c. spacing at least 2.0 d_b
	Case 2:	Cover less than 1.0 d_b or c.-c. spacing less than 2.0 d_b
All Others:	Case 1:	Cover at least 1.0 d_b and c.-c. spacing at least 3.0 d_b
	Case 2:	Cover less than 1.0 d_b or c.-c. spacing less than 3.0 d_b

4. Lap splice lengths are multiples of tension development lengths; Class A = 1.0 ℓ_d and Class B = 1.3 ℓ_d (ACI 318-95, Section 12.15.1).
5. ACI 318-95 does not allow tension lap splices of #14 or #18 bars. The tabulated values for those bar sizes are the tension development lengths.
6. Top bars are horizontal bars with more than 12 in. of concrete cast below the bars.
7. For lightweight aggregate concrete, multiply the tabulated values by 1.3.
8. For epoxy-coated bars, if the bar c.-c. spacing is at least 7.0 d_b and the concrete cover is at least 3.0 d_b, then Case 1 lengths may be multiplied by 0.918 (for top bars) or 0.8 (for other bars).

TABLE 3—TENSION DEVELOPMENT AND LAP SPLICE LENGTHS FOR UNCOATED BARS (AASHTO, Inch-Pound Values)

Bar Size	Lap Class	Lengths (in.) per Concrete Strength (psi)											
		3500 psi				4000 psi				5000 psi			
		Top Bars		Other Bars		Top Bars		Other Bars		Top Bars		Other Bars	
		Cat. 1	Cat. 2	Cat. 1	Cat. 2	Cat. 1	Cat. 2	Cat. 1	Cat. 2	Cat. 1	Cat. 2	Cat. 1	Cat. 2
#3	A	12	13	12	12	12	13	12	12	12	13	12	12
	B	13	17	12	12	13	17	12	12	13	17	12	12
	C	17	22	13	16	17	22	13	16	17	22	13	16
#4	A	14	17	12	12	14	17	12	12	14	17	12	12
	B	18	22	13	16	18	22	13	16	18	22	13	16
	C	23	29	17	21	23	29	17	21	23	29	17	21
#5	A	17	21	12	15	17	21	12	15	17	21	12	15
	B	22	28	16	20	22	28	16	20	22	28	16	20
	C	29	36	21	26	29	36	21	26	29	36	21	26
#6	A	20	25	15	18	20	25	15	18	20	25	15	18
	B	27	33	19	24	27	33	19	24	27	33	19	24
	C	35	43	25	31	35	43	25	31	35	43	25	31
#7	A	28	34	20	25	26	32	19	23	24	30	17	21
	B	36	45	26	32	33	42	24	30	31	39	22	28
	C	47	58	33	42	44	54	31	39	40	50	29	36
#8	A	36	45	26	32	34	42	24	30	30	38	22	27
	B	47	59	34	42	44	55	31	39	39	49	28	35
	C	61	77	44	55	57	72	41	51	51	64	37	46
#9	A	46	57	33	41	43	53	31	38	38	48	27	34
	B	59	74	42	53	56	69	40	50	50	62	36	44
	C	78	97	55	69	73	91	52	65	65	81	46	58
#10	A	58	72	42	52	54	68	39	48	49	61	35	43
	B	75	94	54	67	70	88	50	63	63	79	45	56
	C	98	123	70	88	92	115	66	82	82	103	59	74
#11	A	71	89	51	64	67	83	48	59	60	74	43	53
	B	92	115	66	83	86	108	62	77	77	97	55	69
	C	121	151	86	108	113	141	81	101	101	126	72	90
#14	N/A	97	121	69	87	91	113	65	81	81	101	58	72
#18	N/A	125	156	90	112	117	146	84	105	105	131	75	94

Notes:

1. Tabulated values are based on Grade 60 reinforcing bars and normal weight concrete. Lengths are in inches.
2. Tension development lengths and tension lap splice lengths are calculated per the AASHTO Standard Specifications for Highway Bridges (16th Edition, 1996), Articles 8.25 and 8.32, respectively. Tabulated values for beams or columns are based on transverse reinforcement and concrete cover meeting minimum AASHTO requirements.
3. Categories 1 and 2, which depend on side concrete cover, and the center-to-center spacing of the bars, are defined as:
   Category 1: Side cover at least 3 in. **and** c.-c. spacing at least 6 in.
   Category 2: Side cover less than 3 in. **or** c.-c. spacing less than 6 in.
4. Lap splice lengths are multiples of tension development lengths; Class A = 1.0 ℓ_d, Class B = 1.3 ℓ_d and Class C = 1.7 ℓ_d (AASHTO, Article 8.32.3.1).
5. The AASHTO Bridge Specifications do not allow tension lap splices of #14 or #18 bars. The tabulated values for those bar sizes are the tension development lengths.
6. Top bars are horizontal bars with more than 12 in. of concrete cast below the bars.
7. For lightweight aggregate concrete, multiply the tabulated values by 1.33.

TABLE 3 (CONT.)—TENSION DEVELOPMENT AND LAP SPLICE LENGTHS FOR UNCOATED BARS (AASHTO, Inch-Pound Values)

Bar Size	Lap Class	Lengths (in.) per Concrete Strength (psi)											
		6000 psi				7000 psi				8000 psi			
		Top Bars		Other Bars		Top Bars		Other Bars		Top Bars		Other Bars	
		Cat. 1	Cat. 2	Cat. 1	Cat. 2	Cat. 1	Cat. 2	Cat. 1	Cat. 2	Cat. 1	Cat. 2	Cat. 1	Cat. 2
#3	A	12	13	12	12	12	13	12	12	12	13	12	12
	B	13	17	12	12	13	17	12	12	13	17	12	12
	C	17	22	13	16	17	22	13	16	17	22	13	16
#4	A	14	17	12	12	14	17	12	12	14	17	12	12
	B	18	22	13	16	18	22	13	16	18	22	13	16
	C	23	29	17	21	23	29	17	21	23	29	17	21
#5	A	17	21	12	15	17	21	12	15	17	21	12	15
	B	22	28	16	20	22	28	16	20	22	28	16	20
	C	29	36	21	26	29	36	21	26	29	36	21	26
#6	A	20	25	15	18	20	25	15	18	20	25	15	18
	B	27	33	19	24	27	33	19	24	27	33	19	24
	C	35	43	25	31	35	43	25	31	35	43	25	31
#7	A	24	30	17	21	24	30	17	21	24	30	17	21
	B	31	39	22	28	31	39	22	28	31	39	22	28
	C	40	50	29	36	40	50	29	36	40	50	29	36
#8	A	28	35	20	25	27	34	20	24	27	34	20	24
	B	36	45	26	32	35	44	25	31	35	44	25	31
	C	47	59	34	42	46	57	33	41	46	57	33	41
#9	A	35	44	25	31	32	40	23	29	31	38	22	27
	B	45	57	33	41	42	53	30	38	40	50	28	35
	C	59	74	42	53	55	69	39	49	52	65	37	46
#10	A	44	55	32	40	41	51	29	37	38	48	28	34
	B	58	72	41	51	53	67	38	48	50	62	36	45
	C	75	94	54	67	70	87	50	62	65	81	47	58
#11	A	54	68	39	49	50	63	36	45	47	59	34	42
	B	71	88	51	63	65	82	47	58	61	76	44	55
	C	92	115	66	82	86	107	61	76	80	100	57	71
#14	N/A	74	92	53	66	69	86	49	61	64	80	46	57
#18	N/A	96	120	68	86	89	111	63	79	83	104	59	74

Notes:

1. Tabulated values are based on Grade 60 reinforcing bars and normal weight concrete. Lengths are in inches.
2. Tension development lengths and tension lap splice lengths are calculated per the AASHTO Standard Specifications for Highway Bridges (16th Edition, 1996), Articles 8.25 and 8.32, respectively. Tabulated values for beams or columns are based on transverse reinforcement and concrete cover meeting minimum AASHTO requirements.
3. Categories 1 and 2, which depend on side concrete cover, and the center-to-center spacing of the bars, are defined as:

   Category 1: Side cover at least 3 in. **and** c.-c. spacing at least 6 in.

   Category 2: Side cover less than 3 in. **or** c.-c. spacing less than 6 in.
4. Lap splice lengths are multiples of tension development lengths: Class A = 1.0 ℓ_d, Class B = 1.3 ℓ_d and Class C = 1.7 ℓ_d (AASHTO, Article 8.32.3.1).
5. The AASHTO Bridge Specifications do not allow tension lap splices of #14 or #18 bars. The tabulated values for those bar sizes are the tension development lengths
6. Top bars are horizontal bars with more than 12 in. of concrete cast below the bars.
7. For lightweight aggregate concrete, multiply the tabulated values by 1.33

TABLE 4—TENSION DEVELOPMENT AND LAP SPLICE LENGTHS FOR EPOXY-COATED BARS (AASHTO, Inch-Pound Values)

Bar Size	Lap Class	Lengths (in.) per Concrete Strength (psi)											
		3500 psi				4000 psi				5000 psi			
		Top Bars		Other Bars		Top Bars		Other Bars		Top Bars		Other Bars	
		Cat. 1	Cat. 2	Cat. 1	Cat. 2	Cat. 1	Cat. 2	Cat. 1	Cat. 2	Cat. 1	Cat. 2	Cat. 1	Cat. 2
#3	A	13	16	12	14	13	16	12	14	13	16	12	14
	B	16	20	14	18	16	20	14	18	16	20	14	18
	C	21	26	19	23	21	26	19	23	21	26	19	23
#4	A	17	21	15	18	17	21	15	18	17	21	15	18
	B	22	27	19	24	22	27	19	24	22	27	19	24
	C	28	35	25	31	28	35	25	31	28	35	25	31
#5	A	21	26	18	23	21	26	18	23	21	26	18	23
	B	27	33	24	30	27	33	24	30	27	33	24	30
	C	35	44	31	39	35	44	31	39	35	44	31	39
#6	A	25	31	22	27	25	31	22	27	25	31	22	27
	B	32	40	28	35	32	40	28	35	32	40	28	35
	C	42	52	37	46	42	52	37	46	42	52	37	46
#7	A	33	42	30	37	31	39	28	34	29	36	26	32
	B	43	54	38	48	41	51	36	45	37	47	33	41
	C	57	71	50	62	53	66	47	58	49	61	43	54
#8	A	44	55	39	48	41	51	36	45	37	46	32	41
	B	57	71	50	63	53	67	47	59	48	60	42	53
	C	74	93	66	82	70	87	61	77	62	78	55	69
#9	A	55	69	49	61	52	65	46	57	46	58	41	51
	B	72	90	64	79	67	84	59	74	60	75	53	66
	C	94	118	83	104	88	110	78	97	79	98	70	87
#10	A	70	88	62	78	66	82	58	73	59	74	52	65
	B	91	114	81	101	86	107	75	94	77	96	68	84
	C	119	149	105	132	112	140	99	123	100	125	88	110
#11	A	86	108	76	95	81	101	71	89	72	90	64	80
	B	112	140	99	124	105	131	93	116	94	117	83	104
	C	147	183	129	162	137	171	121	151	123	153	108	135
#14	N/A	118	147	104	130	110	137	97	121	98	123	87	108
#18	N/A	152	190	134	168	142	178	126	157	127	159	112	140

Notes:

1. Tabulated values are based on Grade 60 reinforcing bars and normal weight concrete. Lengths are in inches.
2. Tension development lengths and tension lap splice lengths are calculated per the AASHTO Standard Specifications for Highway Bridges (16th Edition, 1996), Articles 8.25 and 8.32, respectively. Tabulated values for beams or columns are based on transverse reinforcement and concrete cover meeting minimum AASHTO requirements.
3. Categories 1 and 2, which depend on side concrete cover, and the center-to-center spacing of the bars, are defined as:
   Category 1: Side cover at least 3 in. **and** c.-c. spacing at least 6 in.
   Category 2: Side cover less than 3 in. **or** c.-c. spacing less than 6 in.
4. Lap splice lengths are multiples of tension development lengths; Class A = 1.0 ℓ_d, Class B = 1.3 ℓ_d and Class C = 1.7 ℓ_d (AASHTO, Article 8.32.3.1).
5. The AASHTO Bridge Specifications do not allow tension lap splices of #14 or #18 bars. The tabulated values for those bar sizes are the tension development lengths.
6. Top bars are horizontal bars with more than 12 in. of concrete cast below the bars.
7. For lightweight aggregate concrete, multiply the tabulated values by 1.33.
8. For epoxy-coated bars, if the bar c.-c. spacing is at least 7.0 d_b and the concrete cover is at least 3.0 d_b, then Category 1 lengths may be multiplied by 0.947 (for top bar) or 0.767 (for other bars).

TABLE 4 (CONT.)—TENSION DEVELOPMENT AND LAP SPLICE LENGTHS FOR EPOXY-COATED BARS (AASHTO, Inch-Pound Values)

Bar Size	Lap Class	Lengths (in.) per Concrete Strength (psi)											
		6000 psi				7000 psi				8000 psi			
		Top Bars		Other Bars		Top Bars		Other Bars		Top Bars		Other Bars	
		Cat. 1	Cat. 2	Cat. 1	Cat. 2	Cat. 1	Cat. 2	Cat. 1	Cat. 2	Cat. 1	Cat. 2	Cat. 1	Cat. 2
#3	A	13	16	12	14	13	16	12	14	13	16	12	14
	B	16	20	14	18	16	20	14	18	16	20	14	18
	C	21	26	19	23	21	26	19	23	21	26	19	23
#4	A	17	21	15	18	17	21	15	18	17	21	15	18
	B	22	27	19	24	22	27	19	24	22	27	19	24
	C	28	35	25	31	28	35	25	31	28	35	25	31
#5	A	21	26	18	23	21	26	18	23	21	26	18	23
	B	27	33	24	30	27	33	24	30	27	33	24	30
	C	35	44	31	39	35	44	31	39	35	44	31	39
#6	A	25	31	22	27	25	31	22	27	25	31	22	27
	B	32	40	28	35	32	40	28	35	32	40	28	35
	C	42	52	37	46	42	52	37	46	42	52	37	46
#7	A	29	36	26	32	29	36	26	32	29	36	26	32
	B	37	47	33	41	37	47	33	41	37	47	33	41
	C	49	61	43	54	49	61	43	54	49	61	43	54
#8	A	34	42	30	37	33	41	29	36	33	41	29	36
	B	44	54	38	48	43	53	38	47	43	53	38	47
	C	57	71	50	63	56	70	49	62	56	70	49	62
#9	A	42	53	37	47	39	49	35	43	37	46	33	41
	B	55	69	49	61	51	64	45	56	48	60	43	53
	C	72	90	64	79	67	83	59	73	63	79	56	69
#10	A	54	67	48	59	50	62	44	55	47	58	41	51
	B	70	87	62	77	65	81	57	71	61	76	53	67
	C	91	114	81	101	85	106	75	93	79	99	70	87
#11	A	66	82	58	73	61	76	54	67	57	71	51	63
	B	86	107	76	95	79	99	70	88	74	93	66	82
	C	112	140	99	124	104	130	92	114	97	121	86	107
#14	N/A	90	112	79	99	83	104	73	92	78	97	69	86
#18	N/A	116	145	103	128	108	134	95	119	101	126	89	111

Notes:

1. Tabulated values are based on Grade 60 reinforcing bars and normal weight concrete. Lengths are in inches.
2. Tension development lengths and tension lap splice lengths are calculated per the AASHTO Standard Specifications for Highway Bridges (16th Edition, 1996), Articles 8.25 and 8.32, respectively. Tabulated values for beams or columns are based on transverse reinforcement and concrete cover meeting minimum AASHTO requirements.
3. Categories 1 and 2, which depend on side concrete cover, and the center-to-center spacing of the bars, are defined as:
   Category 1: Side cover at least 3 in. **and** c.-c. spacing at least 6 in.
   Category 2: Side cover less than 3 in. **or** c.-c. spacing less than 6 in.
4. Lap splice lengths are multiples of tension development lengths; Class A = 1.0 ℓ_d, Class B = 1.3 ℓ_d and Class C = 1.7 ℓ_d (AASHTO, Article 8.32.3.1).
5. The AASHTO Bridge Specifications do not allow tension lap splices of #14 or #18 bars. The tabulated values for those bar sizes are the tension development lengths.
6. Top bars are horizontal bars with more than 12 in. of concrete cast below the bars.
7. For lightweight aggregate concrete, multiply the tabulated values by 1.33.
8. For epoxy-coated bars, if the bar c.-c. spacing is at least 7.0 d_b and the concrete cover is at least 3.0 d_b, then Category 1 lengths may be multiplied by 0.947 (for top bars) or 0.767 (for other bars).

TABLE 5—TENSION DEVELOPMENT AND LAP SPLICE LENGTHS FOR BARS IN WALLS AND SLABS (ACI 318, Inch-Pound Values)

f'_c = 3000 psi

Bar Size	Lap Class	Concrete Cover = 0.75 in.				Concrete Cover = 1.00 in.				Concrete Cover = 1.50 in.				Concrete Cover = 2.00 in.			
		Uncoated		Epoxy-Coated		Uncoated		Epoxy-Coated		Uncoated		Epoxy-Coated		Uncoated		Epoxy-Coated	
		Top	Other	Top	Other	Top	Other	Top	Other	Top	Other	Top	Other	Top	Other	Top	Other
#3	A	13	12	17	15	13	12	17	15	13	12	16	12	13	12	16	12
	B	17	16	22	20	17	16	22	20	17	16	20	16	17	16	20	16
#4	A	22	17	28	25	17	13	23	20	17	13	21	16	17	13	21	16
	B	28	22	37	32	23	17	29	26	23	17	27	21	23	17	27	21
#5	A	32	24	41	37	26	20	34	30	22	17	28	25	22	17	26	20
	B	41	32	54	47	33	26	44	38	28	22	37	32	28	22	34	26
#6	A	43	33	56	50	35	27	46	41	26	20	34	30	26	20	34	30
	B	56	43	73	64	46	35	60	53	34	26	44	39	34	26	44	39
#7	A	69	53	90	80	57	44	75	66	43	33	55	49	38	29	49	43
	B	90	69	117	104	74	57	97	86	55	43	72	64	49	38	64	56
#8	A	86	66	112	99	72	55	93	82	54	41	70	62	43	33	56	50
	B	111	86	146	128	93	72	121	107	70	54	91	80	56	43	73	64
#9	A	104	80	136	120	87	67	114	101	66	51	86	76	53	41	70	61
	B	135	104	176	155	113	87	148	131	86	66	112	99	69	53	90	80
#10	A	125	96	163	144	106	81	138	122	81	62	106	93	66	51	86	76
	B	162	125	212	187	137	106	179	158	105	81	137	121	85	66	111	98
#11	A	146	113	191	169	125	96	163	144	97	74	126	111	79	61	103	91
	B	190	146	248	219	162	125	212	187	125	97	164	145	102	79	134	118

Notes:

1. Tabulated values are based on Grade 60 reinforcing bars and normal weight concrete. Lengths are in inches.
2. Tension development lengths and tension lap splice lengths are calculated per ACI 318-95, Sections 12.2.3 and 12.15, respectively.
3. Lap splice lengths are multiples of tension development lengths; Class A = 1.0 ℓ_d and Class B = 1.3 ℓ_d (ACI 318-95, Section 12.15.1).
4. Bar sizes #14 and #18 were intentionally omitted from this table.
5. Top bars are horizontal bars with more than 12 in. of concrete cast below the bars.
6. For lightweight aggregate concrete, multiply the tabulated values by 1.3.

TABLE 6—TENSION DEVELOPMENT AND LAP SPLICE LENGTHS FOR BARS IN WALLS AND SLABS (ACI 318, Inch-Pound Values)

f'_c = 4000 psi

Bar Size	Lap Class	Concrete Cover = 0.75 in.				Concrete Cover = 1.00 in.				Concrete Cover = 1.50 in.				Concrete Cover = 2.00 in.			
		Uncoated		Epoxy-Coated		Uncoated		Epoxy-Coated		Uncoated		Epoxy-Coated		Uncoated		Epoxy-Coated	
		Top	Other	Top	Other	Top	Other	Top	Other	Top	Other	Top	Other	Top	Other	Top	Other
#3	A	12	12	15	13	12	12	15	13	12	12	14	12	12	12	14	12
	B	16	16	19	17	16	16	19	17	16	16	18	16	16	16	18	16
#4	A	19	15	24	22	15	12	20	17	15	12	18	14	15	12	18	14
	B	24	19	32	28	20	16	25	22	20	16	23	18	20	16	23	18
#5	A	28	21	36	32	22	17	29	26	19	15	24	22	19	15	22	17
	B	36	28	47	41	29	22	38	33	24	19	32	28	24	19	29	22
#6	A	37	29	49	43	31	24	40	35	22	17	29	26	22	17	29	26
	B	48	37	63	56	40	31	52	46	29	22	38	34	29	22	38	34
#7	A	60	46	78	69	50	38	65	57	37	28	48	42	33	25	43	38
	B	78	60	102	90	64	50	84	74	48	37	62	55	42	33	55	49
#8	A	74	57	97	86	62	48	81	71	47	36	61	54	37	29	49	43
	B	96	74	126	111	80	62	105	93	60	47	79	70	48	37	63	56
#9	A	90	69	117	104	76	58	99	87	57	44	75	66	46	36	60	53
	B	117	90	153	135	98	76	128	113	74	57	97	86	60	46	78	69
#10	A	108	83	141	125	92	70	120	106	70	54	92	81	57	44	74	66
	B	140	108	183	162	119	92	155	137	91	70	119	105	74	57	97	85
#11	A	127	98	166	146	108	83	141	125	84	64	109	97	68	53	89	79
	B	165	127	215	190	141	108	184	162	109	84	142	125	89	68	116	102

Notes:

1. Tabulated values are based on Grade 60 reinforcing bars and normal weight concrete. Lengths are in inches.
2. Tension development lengths and tension lap splice lengths are calculated per ACI 318-95, Sections 12.2.3 and 12.15, respectively.
3. Lap splice lengths are multiples of tension development lengths: Class A = 1.0 ℓ_d and Class B = 1.3 ℓ_d (ACI 318-95, Section 12.15.1).
4. Bar sizes #14 and #18 were intentionally omitted from this table.
5. Top bars are horizontal bars with more than 12 in. of concrete cast below the bars.
6. For lightweight aggregate concrete, multiply the tabulated values by 1.3

TABLE 7—TENSION DEVELOPMENT LENGTHS FOR UNCOATED BARS IN SEISMIC JOINTS
(ACI 318, Inch-Pound Values)

Bar Size	Lengths (in.) per Concrete Strength (psi)											
	3000 psi		4000 psi		5000 psi		6000 psi		7000 psi		8000 psi	
	Top	Other	Top	Other	Top	Other	Top	Other	Top	Other	Top	Other
#3	22	16	21	15	21	15	21	15	21	15	21	15
#4	30	21	26	19	23	17	21	15	21	15	21	15
#5	37	27	32	23	29	21	26	19	24	18	23	16
#6	45	32	39	28	35	25	32	23	29	21	27	20
#7	52	37	45	32	40	29	37	26	34	24	32	23
#8	59	42	51	37	46	33	42	30	39	28	36	26
#9	67	48	58	41	52	37	47	34	44	31	41	29
#10	75	54	65	47	58	42	53	38	49	35	46	33
#11	83	60	72	52	65	46	59	42	55	39	51	37

Notes:
1. Tabulated values are based on Grade 60 reinforcing bars and normal weight concrete. Lengths are in inches.
2. Tension development lengths are calculated per ACI 318-95, Section 21.5.4.2, where bar sizes are limited to #3 through #11.
3. Top bars are horizontal bars with more than 12 in. of concrete cast below the bars.

TABLE 8—TENSION DEVELOPMENT LENGTHS FOR EPOXY-COATED BARS IN SEISMIC JOINTS
(ACI 318, Inch-Pound Values)

Bar Size	Lengths (in.) per Concrete Strength (psi)											
	3000 psi		4000 psi		5000 psi		6000 psi		7000 psi		8000 psi	
	Top	Other	Top	Other	Top	Other	Top	Other	Top	Other	Top	Other
#3	27	24	26	23	26	23	26	23	26	23	26	23
#4	36	32	31	28	28	25	26	23	26	23	26	23
#5	45	40	39	35	35	31	32	28	30	26	28	24
#6	54	48	47	41	42	37	38	34	35	31	33	29
#7	63	56	55	48	49	43	45	39	41	37	39	34
#8	72	63	62	55	56	49	51	45	47	42	44	39
#9	81	72	70	62	63	56	57	51	53	47	50	44
#10	91	81	79	70	71	62	65	57	60	53	56	49
#11	101	89	88	77	79	69	72	63	66	59	62	55

Notes:
1. Tabulated values are based on Grade 60 reinforcing bars and normal weight concrete. Lengths are in inches.
2. Tension development lengths are calculated per ACI 318-95, Section 21.5.4.2, where bar sizes are limited to #3 through #11.
3. Top bars are horizontal bars with more than 12 in. of concrete cast below the bars.

TABLE 9—TENSION DEVELOPMENT LENGTHS OF STANDARD HOOKS FOR UNCOATED BARS (ACI 318 and AASHTO, Inch-Pound Values)

Bar Size	Length (in.) per Concrete Strength (psi)						
	3000 psi	3500 psi	4000 psi	5000 psi	6000 psi	7000 psi	8000 psi
#3	9	8	7	7	6	6	6
#4	11	10	10	9	8	7	7
#5	14	13	12	11	10	9	9
#6	17	16	15	13	12	11	10
#7	19	18	17	15	14	13	12
#8	22	21	19	17	16	15	14
#9	25	23	22	19	18	16	15
#10	28	26	24	22	20	19	17
#11	31	29	27	24	22	21	19
#14	37	35	32	29	27	25	23
#18	50	46	43	39	35	33	31

Notes:

1. Tabulated values are based on Grade 60 reinforcing bars and normal weight concrete. Lengths are in inches.
2. Tension development lengths of standard hooks are calculated per ACI 318-95, Section 12.5 and the AASHTO Bridge Specifications for Highway Bridges (16th Edition, 1996), Article 8.29.
3. For bar sizes #3 through #11 only:
   a. If concrete cover conforms to ACI 318-95 (Section 12.5.3.3) or AASHTO (Article 8.29.3.2), then a modification factor of 0.7 may be applied but the length must not be less than 8.0 d_b nor 6 in.
   b. If hook is enclosed in ties or stirrups per ACI 318-95 (Section 12.5.3.3) or AASHTO (Article 8.29.3.3), then a modification factor of 0.8 may be applied but the length must not be less than 8.0 d_b nor 6 in.
4. For lightweight aggregate concrete, multiply the tabulated values by 1.3.

TABLE 10—TENSION DEVELOPMENT LENGTHS OF STANDARD HOOKS FOR UNCOATED BARS (ACI 318 and AASHTO, Inch-Pound Values)

Bar Size	Length (in.) per Concrete Strength (psi)						
	3000 psi	3500 psi	4000 psi	5000 psi	6000 psi	7000 psi	8000 psi
#3	10	9	9	8	7	7	6
#4	13	12	12	10	10	9	8
#5	17	16	15	13	12	11	10
#6	20	19	17	16	14	13	12
#7	23	22	20	18	17	15	14
#8	27	25	23	21	19	18	16
#9	30	28	26	23	21	20	18
#10	34	31	29	26	24	22	21
#11	37	35	32	29	27	25	23
#14	45	42	39	35	32	29	28
#18	60	55	52	46	42	39	37

Notes:

1. Tabulated values are based on Grade 60 reinforcing bars and normal weight concrete. Lengths are in inches.
2. Tension development lengths of standard hooks are calculated per ACI 318-95, Section 12.5 and the AASHTO Bridge Specifications for Highway Bridges (16th Edition, 1996), Article 8.29.
3. For bar sizes #3 through #11 only:
   a. If concrete cover conforms to ACI 318-95 (Section 12.5.3.3) or AASHTO (Article 8.29.3.2), then a modification factor of 0.7 may be applied but the length must not be less than 8.0 d_b nor 6 in.
   b. If hook is enclosed in ties or stirrups per ACI 318-95 (Section 12.5.3.3) or AASHTO (Article 8.29.3.3), then a modification factor of 0.8 may be applied but the length must not be less than 8.0 d_b nor 6 in.
4. For lightweight aggregate concrete, multiply the tabulated values by 1.3.

TABLE 11—TENSION DEVELOPMENT LENGTHS OF STANDARD HOOKS FOR UNCOATED BARS IN SEISMIC JOINTS (ACI 318, Inch-Pound Values)

Bar Size	Lengths (in.) per Concrete Strengths (psi)					
	3000 psi	4000 psi	5000 psi	6000 psi	7000 psi	8000 psi
#3	7	6	6	6	6	6
#4	9	8	7	6	6	6
#5	11	9	8	8	7	7
#6	13	11	10	9	9	8
#7	15	13	12	11	10	9
#8	17	15	13	12	11	11
#9	19	17	15	14	13	12
#10	22	19	17	15	14	13
#11	24	21	19	17	16	15

Notes:
1. Tabulated values are based on Grade 60 reinforcing bars and normal weight concrete. Lengths are in inches.
2. Tension development lengths of standard hooks are calculated per ACI 318-95, Section 21.5.4.1, where bar sizes are limited to #3 through #11.

TABLE 12—TENSION DEVELOPMENT LENGTHS OF STANDARD HOOKS FOR EPOXY-COATED BARS IN SEISMIC JOINTS (ACI 318, Inch-Pound Values)

Bar Size	Lengths (in.) per Concrete Strengths (psi)					
	3000 psi	4000 psi	5000 psi	6000 psi	7000 psi	8000 psi
#3	8	8	8	8	8	8
#4	10	9	8	8	8	8
#5	13	11	10	9	9	8
#6	15	13	12	11	10	10
#7	18	16	14	13	12	11
#8	21	18	16	15	14	13
#9	23	20	18	16	15	14
#10	26	23	20	18	17	16
#11	29	25	22	20	19	18

Notes:
1. Tabulated values are based on Grade 60 reinforcing bars and normal weight concrete. Lengths are in inches.
2. Tension development lengths of standard hooks are calculated per ACI 318-95, Section 21.5.4.1, where bar sizes are limited to #3 through #11.

TABLE 13—COMPRESSION DEVELOPMENT AND LAP SPLICE LENGTHS FOR UNCOATED AND EPOXY-COATED BARS (ACI 318 and AASHTO, Inch-Pound Values)

Bar Size	Compression Length (in.) per Concrete Strength (psi)							Lap Splice
	3000 psi	3500 psi	4000 psi	5000 psi	6000 psi	7000 psi	8000 psi	
#3	9	8	8	8	8	8	8	12
#4	11	10	10	9	9	9	9	15
#5	14	13	12	12	12	12	12	19
#6	17	16	15	14	14	14	14	23
#7	19	18	17	16	16	16	16	27
#8	22	21	19	18	18	18	18	30
#9	25	23	22	21	21	21	21	34
#10	28	26	24	23	23	23	23	38
#11	31	29	27	26	26	26	26	43
#14	37	35	32	31	31	31	31	N/A
#18	50	46	43	41	41	41	41	N/A

Notes:

1. Tabulated values are based on Grade 60 reinforcing bars and normal weight concrete. Lengths are in inches.
2. Compression development lengths are calculated per ACI 318-95, Section 12.3, and AASHTO Standard Specifications for Highway Bridges (16th Edition, 1996), Article 8.26. Compression lap splice lengths are calculated per ACI 318-95, Section 12.16, and AASHTO Standard Specifications for Highway Bridges (16th Edition, 1996), Article 8.32.4.
3. For compression development lengths, if bars are enclosed in spirals or ties per ACI 318-95, Section 12.3.3.2, or AASHTO, Article 8.26.2.2, then a modification factor of 0.75 may be applied but the length must not be less than 8 in.
4. For compression lap splice lengths:
   a. If bars are enclosed in a tied compression member per ACI 318-95, Section 12.17.2.4, or AASHTO, Article 8.32.4.1, then a modification factor of 0.83 may be applied but the length must not be less than 12 in.
   b. If bars are enclosed in a spirally-reinforced compression member per ACI 318-95, Section 12.17.2.5, or AASHTO, Article 8.32.4.1, then a modification factor of 0.75 may be applied but the length must not be less than 12 in.
5. ACI 318-95 and AASHTO do not allow compression lap splices of #14 and #18 bars, except to #11 and smaller bars

TABLE 14—TENSION DEVELOPMENT AND LAP SPLICE LENGTHS FOR DEFORMED WIRE
f'_c = 4000 psi (ACI 318, Inch-Pound Values)

Wire Size	Development Length (in.)		Lap Splice Length, in. (Class B)	
	Top	Other	Top	Other
D-1	12	12	16	16
D-2	12	12	16	16
D-3	12	12	16	16
D-4	14	12	18	16
D-5	16	12	20	16
D-6	17	13	22	17
D-7	18	14	24	18
D-8	20	15	26	20
D-9	21	16	27	21
D-10	22	17	29	22
D-11	23	18	30	23
D-12	24	19	31	24
D-13	25	19	33	25
D-14	26	20	34	26
D-15	27	21	35	27
D-16	28	21	36	28
D-17	29	22	37	29
D-18	30	23	38	30
D-19	30	23	39	30
D-20	31	24	40	31
D-21	32	25	41	32
D-22	33	25	42	33
D-23	33	26	43	33
D-24	34	26	44	34
D-25	35	27	45	35
D-26	35	27	46	35
D-27	36	28	47	36
D-28	37	28	48	37
D-29	37	29	49	37
D-30	38	29	50	38
D-31	39	30	50	39
D-45	47	36	61	47

Notes:

1. Tabulated values are based on a minimum yield strength of 75,000 psi and 4,000 psi normal weight concrete. Lengths are in inches.
2. Tension development lengths and tension lap splice lengths are calculated per ACI 318-95, Sections 12.2.2 and 12.15, respectively.
3. Lap splice lengths are multiples of tension development lengths: Class A = 1.0 ℓ_d and Class B = 1.3 ℓ_d (ACI 318-95, Section 12.15.1). Lap Class B was assumed for the tables.
4. Top wires are horizontal wires with more than 12 in. of concrete cast below the wires.
5. For lightweight aggregate concrete, multiply the tabulated values by 1.3.

TABLE 15—TENSION DEVELOPMENT LENGTHS FOR DEFORMED WELDED WIRE FABRIC (ACI 318, Inch-Pound Values)

f'_c = 4000 psi

Wire Size	For Top WWF per Wire Spacing (in.)				For Other WWF per Wire Spacing (in.)			
	4	6	8	12	4	6	8	12
D-1	4	4	4	4	4	4	4	4
D-2	5	5	5	5	4	4	4	4
D-3	6	6	6	6	4	4	4	4
D-4	6	6	6	6	5	5	5	5
D-5	7	7	7	7	6	6	6	6
D-6	8	8	8	8	6	6	6	6
D-7	9	9	9	9	7	7	7	7
D-8	9	9	9	9	7	7	7	7
D-9	10	10	10	10	7	7	7	7
D-10	10	10	10	10	8	8	8	8
D-11	11	11	11	11	8	8	8	8
D-12	11	11	11	11	9	9	9	9
D-13	12	12	12	12	9	9	9	9
D-14	13	12	12	12	10	9	9	9
D-15	14	13	13	13	11	10	10	10
D-16	15	13	13	13	11	10	10	10
D-17	16	13	13	13	12	10	10	10
D-18	16	14	14	14	13	11	11	11
D-19	17	14	14	14	13	11	11	11
D-20	18	15	15	15	14	11	11	11
D-21	19	15	15	15	15	11	11	11
D-22	20	15	15	15	16	12	12	12
D-23	21	16	16	16	16	12	12	12
D-24	22	16	16	16	17	12	12	12
D-25	23	16	16	16	18	12	12	12
D-26	24	17	17	17	18	13	13	13
D-27	25	17	17	17	19	13	13	13
D-28	26	17	17	17	20	13	13	13
D-29	27	18	17	17	20	14	13	13
D-30	27	18	18	18	21	14	14	14
D-31	28	19	18	18	22	15	14	14
D-45	41	27	22	22	32	21	17	17

Notes:

1. Tabulated values are based on a minimum yield strength of 70,000 psi and 4,000 psi normal weight concrete. Lengths are in inches.
2. Tension development lengths are calculated per ACI 318-95, Section 12.7.
3. Top WWF is horizontal WWF with more than 12 in. of concrete cast below the WWF.
4. For lightweight aggregate concrete, multiply the tabulated values by 1.3.

TABLE 16—TENSION LAP SPLICE LENGTHS FOR DEFORMED WELDED WIRE FABRIC (ACI 318, Inch-Pound Values)

f'_c = 4000 psi

Wire	For Top WWF per Wire Spacing (in.)				For Other WWF per Wire Spacing (in.)			
Size	4	6	8	12	4	6	8	12
D-1	8	8	8	8	8	8	8	8
D-2	8	8	8	8	8	8	8	8
D-3	8	8	8	8	8	8	8	8
D-4	8	8	8	8	8	8	8	8
D-5	9	9	9	9	8	8	8	8
D-6	10	10	10	10	8	8	8	8
D-7	11	11	11	11	9	9	9	9
D-8	12	12	12	12	9	9	9	9
D-9	13	13	13	13	10	10	10	10
D-10	13	13	13	13	10	10	10	10
D-11	14	14	14	14	11	11	11	11
D-12	15	15	15	15	11	11	11	11
D-13	15	15	15	15	12	12	12	12
D-14	17	16	16	16	13	12	12	12
D-15	18	16	16	16	14	13	13	13
D-16	19	17	17	17	15	13	13	13
D-17	20	17	17	17	16	13	13	13
D-18	21	18	18	18	16	14	14	14
D-19	23	18	18	18	17	14	14	14
D-20	24	19	19	19	18	15	15	15
D-21	25	19	19	19	19	15	15	15
D-22	26	20	20	20	20	15	15	15
D-23	27	20	20	20	21	16	16	16
D-24	29	21	21	21	22	16	16	16
D-25	30	21	21	21	23	16	16	16
D-26	31	22	22	22	24	17	17	17
D-27	32	22	22	22	25	17	17	17
D-28	33	22	22	22	26	17	17	17
D-29	35	23	23	23	27	18	17	17
D-30	36	24	23	23	27	18	18	18
D-31	37	25	24	24	28	19	18	18
D-45	54	36	28	28	41	27	22	22

Notes:

1. Tabulated values are based on a minimum yield strength of 70,000 psi and 4,000 psi normal weight concrete. Lengths are in inches.
2. Tension lap splice lengths are calculated per ACI 318-95, Section 12.18.
3. Top WWF is horizontal WWF with more than 12 in. of concrete cast below the WWF.
4. For lightweight aggregate concrete, multiply the tabulated values by 1.3.

TABLE 17—TENSION DEVELOPMENT AND LAP SPLICE LENGTHS FOR PLAIN WELDED WIRE FABRIC (ACI 318, Inch-Pound Values)

f'_c = 4000 psi

Wire	Wire Spacing	Development Length (in.) per Cross Wire Spacing (in.)				Lap Splice Length (in.) per Cross Wire Spacing (in.)			
		4	6	8	12	4	6	8	12
W0.5	4	6	6	6	6	6	8	10	14
to	6	6	6	6	6	6	8	10	14
W5.5	12	6	6	6	6	6	8	10	14
W6	4	6	6	6	6	6	8	10	14
	6	6	6	6	6	6	8	10	14
	12	6	6	6	6	6	8	10	14
W8	4	6	6	6	6	8	8	10	14
	6	6	6	6	6	6	8	10	14
	12	6	6	6	6	6	8	10	14
W10	4	7	7	7	7	10	10	10	14
	6	6	6	6	6	7	8	10	14
	12	6	6	6	6	6	8	10	14
W12	4	8	8	8	8	12	12	12	14
	6	6	6	6	6	8	8	10	14
	12	6	6	6	6	6	8	10	14
W14	4	10	10	10	10	15	15	15	15
	6	6	6	6	6	10	10	10	14
	12	6	6	6	6	6	8	10	14
W16	4	11	11	11	11	17	17	17	17
	6	7	7	7	7	11	11	11	14
	12	6	6	6	6	6	8	10	14
W18	4	12	12	12	12	19	19	19	19
	6	8	8	8	8	12	12	12	14
	12	6	6	6	6	6	8	10	14
W20	4	14	14	14	14	21	21	21	21
	6	9	9	9	9	14	14	14	14
	12	6	6	6	6	7	8	10	14
W22	4	15	15	15	15	23	23	23	23
	6	10	10	10	10	15	15	15	15
	12	6	6	6	6	8	8	10	14
W24	4	17	17	17	17	25	25	25	25
	6	11	11	11	11	17	17	17	17
	12	6	6	6	6	8	8	10	14
W26	4	18	18	18	18	27	27	27	27
	6	12	12	12	12	18	18	18	18
	12	6	6	6	6	9	9	10	14
W28	4	19	19	19	19	29	29	29	29
	6	13	13	13	13	19	19	19	19
	12	6	6	6	6	10	10	10	14
W30	4	21	21	21	21	31	31	31	31
	6	14	14	14	14	21	21	21	21
	12	7	7	7	7	10	10	10	14
W31	4	22	22	22	22	32	32	32	32
	6	14	14	14	14	22	22	22	22
	12	7	7	7	7	11	11	11	14
W45	4	31	31	31	31	47	47	47	47
	6	21	21	21	21	31	31	31	31
	12	10	10	10	10	16	16	16	16

Notes:

1. Tabulated values are based on a minimum yield strength of 56,000 psi (smaller than size W1.2) or 65,000 psi (size W1.2 and larger) and 4,000 psi normal weight concrete. Lengths are in inches.
2. Tension development lengths and tension lap splice lengths are calculated per ACI 318-95, Sections 12.8 and 12.19, respectively.
3. For the lap splice lengths, area of steel provided was assumed to be less than twice the area of steel required (ACI 318-95, Section 12.19.1).

TABLE 18—TENSION DEVELOPMENT AND LAP SPLICE LENGTHS FOR UNCOATED BARS (ACI 318M, Metric Values)

Bar Size	Lap Class	Lengths (mm) per Concrete Strength (MPa)											
		21 MPa				28 MPa				35 MPa			
		Top Bars		Other Bars		Top Bars		Other Bars		Top Bars		Other Bars	
		Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2
#10	A	550	820	420	630	470	710	360	550	420	630	330	490
	B	710	1060	550	820	610	920	470	710	550	820	420	630
#13	A	730	1090	560	840	630	950	490	730	570	850	440	650
	B	950	1420	730	1090	820	1230	630	950	730	1100	570	850
#16	A	910	1370	700	1050	790	1180	610	910	710	1060	540	820
	B	1190	1780	910	1370	1030	1540	790	1180	920	1380	710	1060
#19	A	1100	1640	840	1260	950	1420	730	1090	850	1270	650	980
	B	1420	2130	1100	1640	1230	1850	950	1420	1100	1650	850	1270
#22	A	1590	2380	1220	1830	1380	2060	1060	1590	1230	1850	950	1420
	B	2070	3100	1590	2380	1790	2680	1380	2060	1600	2400	1230	1850
#25	A	1820	2730	1400	2100	1580	2360	1210	1820	1410	2110	1080	1630
	B	2360	3540	1820	2730	2050	3070	1580	2360	1830	2750	1410	2110
#29	A	2050	3080	1580	2370	1780	2670	1370	2050	1590	2390	1230	1840
	B	2670	4000	2050	3080	2310	3470	1780	2670	2070	3100	1590	2390
#32	A	2310	3470	1780	2670	2000	3000	1540	2310	1790	2690	1380	2070
	B	3000	4510	2310	3470	2600	3900	2000	3000	2330	3490	1790	2690
#36	A	2560	3840	1970	2960	2220	3330	1710	2560	1990	2980	1530	2290
	B	3330	4990	2560	3840	2880	4320	2220	3330	2580	3870	1990	2980
#43	N/A	3080	4610	2370	3550	2670	4000	2050	3070	2380	3570	1830	2750
#57	N/A	4100	6150	3150	4730	3550	5320	2730	4100	3180	4760	2440	3660

Notes:

1. Tabulated values are based on Grade 420 reinforcing bars and normal density concrete. Lengths are in millimeters.
2. Tension development lengths and tension lap splice lengths are calculated per ACI 318M- 95, Sections 12.2.2 and 12.15, respectively. Tabulated values for beams or columns are based on transverse reinforcement and concrete cover meeting minimum Code requirements.
3. Cases 1 and 2, which depend on the type of structural element, concrete cover, and the center-to-center spacing of the bars, are defined as:

Beams or Columns:	Case 1:	Cover at least 1.0 d_b and c.-c. spacing at least 2.0 d_b
	Case 2:	Cover less than 1.0 d_b or c.-c. spacing less than 2.0 d_b
All Others:	Case 1:	Cover at least 1.0 d_b and c.-c. spacing at least 3.0 d_b
	Case 2:	Cover less than 1.0 d_b or c.-c. spacing less than 3.0 d_b

4. Lap splice lengths are multiples of tension development lengths; Class A = 1.0 ℓd and Class B = 1.3 ℓd (ACI 318M-95, Section 12.15.1).
5. ACI 318M-95 does not allow tension lap splices of #43 or #57 bars. The tabulated values for those bar sizes are the tension development lengths.
6. Top bars are horizontal bars with more than 300 mm of concrete cast below the bars.
7. For lightweight aggregate concrete, multiply the tabulated values by 1.3.

TABLE 18 (CONT.)—TENSION DEVELOPMENT AND LAP SPLICE LENGTHS FOR UNCOATED BARS (ACI 318M, Metric Values)

Bar Size	Lap Class	Lengths (mm) per Concrete Strength (MPa)											
		42 MPa				49 MPa				56 MPa			
		Top Bars		Other Bars		Top Bars		Other Bars		Top Bars		Other Bars	
		Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2
#10	A	390	580	300	450	360	540	300	410	340	500	300	390
	B	500	750	390	580	470	700	390	540	440	650	390	500
#13	A	520	770	400	600	480	720	370	550	450	670	350	520
	B	670	1000	520	770	620	930	480	720	580	870	450	670
#16	A	650	970	500	740	600	900	460	690	560	840	430	650
	B	840	1260	650	970	780	1160	600	900	730	1090	560	840
#19	A	780	1160	600	890	720	1080	550	830	670	1010	520	770
	B	1010	1510	780	1160	930	1400	720	1080	870	1310	670	1010
#22	A	1130	1690	870	1300	1040	1560	800	1200	970	1460	750	1120
	B	1460	2190	1130	1690	1350	2030	1040	1560	1270	1900	970	1460
#25	A	1290	1930	990	1480	1190	1790	920	1370	1110	1670	860	1290
	B	1670	2510	1290	1930	1550	2320	1190	1790	1450	2170	1110	1670
#29	A	1450	2180	1120	1680	1350	2020	1040	1550	1260	1890	970	1450
	B	1890	2830	1450	2180	1750	2620	1350	2020	1640	2450	1260	1890
#32	A	1640	2450	1260	1890	1510	2270	1170	1750	1420	2120	1090	1630
	B	2130	3190	1640	2450	1970	2950	1510	2270	1840	2760	1420	2120
#36	A	1810	2720	1400	2090	1680	2520	1290	1940	1570	2350	1210	1810
	B	2360	3530	1810	2720	2180	3270	1680	2520	2040	3060	1570	2350
#43	N/A	2180	3260	1680	2510	2020	3020	1550	2320	1890	2830	1450	2180
#57	N/A	2900	4350	2230	3350	2680	4030	2070	3100	2510	3770	1930	2900

Notes:

1. Tabulated values are based on Grade 420 reinforcing bars and normal density concrete. Lengths are in millimeters.
2. Tension development lengths and tension lap splice lengths are calculated per ACI 318M- 95, Sections 12.2.2 and 12.15, respectively. Tabulated values for beams or columns are based on transverse reinforcement and concrete cover meeting minimum Code requirements.
3. Cases 1 and 2, which depend on the type of structural element, concrete cover, and the center-to-center spacing of the bars, are defined as:

Beams or Columns:	Case 1:	Cover at least 1.0 d_b **and** c.-c. spacing at least 2.0 d_b
	Case 2:	Cover less than 1.0 d_b **or** c.-c. spacing less than 2.0 d_b
All Others:	Case 1:	Cover at least 1.0 d_b **and** c.-c. spacing at least 3.0 d_b
	Case 2:	Cover less than 1.0 d_b **or** c.-c. spacing less than 3.0 d_b

4. Lap splice lengths are multiples of tension development lengths; Class A = 1.0 ℓd and Class B = 1.3 ℓd (ACI 318M-95, Section 12.15.1).
5. ACI 318M-95 does not allow tension lap splices of #43 or #57 bars. The tabulated values for those bar sizes are the tension development lengths.
6. Top bars are horizontal bars with more than 300 mm of concrete cast below the bars.
7. For lightweight aggregate concrete, multiply the tabulated values by 1.3.

TABLE 19—TENSION DEVELOPMENT AND LAP SPLICE LENGTHS FOR EPOXY-COATED BARS (ACI 318M, Metric Values)

Bar Size	Lap Class	Lengths (mm) per Concrete Strength (MPa)											
		21 MPa				28 MPa				35 MPa			
		Top Bars		Other Bars		Top Bars		Other Bars		Top Bars		Other Bars	
		Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2
#10	A	710	1070	630	940	620	930	550	820	550	830	490	730
	B	930	1390	820	1230	800	1200	710	1060	720	1080	630	950
#13	A	950	1430	840	1260	830	1240	730	1090	740	1110	650	980
	B	1240	1860	1090	1640	1070	1610	950	1420	960	1440	850	1270
#16	A	1190	1790	1050	1580	1030	1550	910	1370	920	1380	820	1220
	B	1550	2320	1370	2050	1340	2010	1180	1770	1200	1800	1060	1590
#19	A	1430	2150	1260	1890	1240	1860	1090	1640	1110	1660	980	1470
	B	1860	2790	1640	2460	1610	2420	1420	2130	1440	2160	1270	1910
#22	A	2080	3120	1830	2750	1800	2700	1590	2380	1610	2410	1420	2130
	B	2700	4050	2380	3570	2340	3510	2060	3100	2090	3140	1850	2770
#25	A	2380	3560	2100	3150	2060	3090	1820	2720	1840	2760	1630	2440
	B	3090	4630	2730	4090	2680	4010	2360	3540	2390	3590	2110	3170
#29	A	2690	4030	2370	3550	2330	3490	2050	3080	2080	3120	1840	2750
	B	3490	5230	3080	4620	3020	4530	2670	4000	2700	4060	2390	3580
#32	A	3020	4530	2670	4000	2620	3930	2310	3460	2340	3510	2070	3100
	B	3930	5890	3470	5200	3400	5100	3000	4500	3040	4560	2690	4030
#36	A	3350	5020	2960	4430	2900	4350	2560	3840	2600	3890	2290	3430
	B	4350	6530	3840	5760	3770	5650	3330	4990	3370	5060	2980	4460
#43	N/A	4020	6030	3550	5320	3480	5220	3070	4610	3120	4670	2750	4120
#57	N/A	5360	8040	4730	7090	4640	6960	4100	6140	4150	6230	3660	5490

Notes:

1. Tabulated values are based on Grade 420 reinforcing bars and normal density concrete. Lengths are in millimeters.
2. Tension development lengths and tension lap splice lengths are calculated per ACI 318M-95, Sections 12.2.2 and 12.15, respectively. Tabulated values for beams or columns are based on transverse reinforcement and concrete cover meeting minimum Code requirements.
3. Cases 1 and 2, which depend on the type of structural element, concrete cover, and the center-to-center spacing of the bars, are defined as:

Beams or Columns:	Case 1:	Cover at least 1.0 d_b **and** c.-c. spacing at least 2.0 d_b
	Case 2:	Cover less than 1.0 d_b **or** c.-c. spacing less than 2.0 d_b
All Others:	Case 1:	Cover at least 1.0 d_b **and** c.-c. spacing at least 3.0 d_b
	Case 2:	Cover less than 1.0 d_b **or** c.-c. spacing less than 3.0 d_b

4. Lap splice lengths are multiples of tension development lengths: Class A = 1.0 ℓ_d and Class B = 1.3 ℓ_d (ACI 318M-95, Section 12.15.1).
5. ACI 318M-95 does not allow tension lap splices of #43 or #57 bars. The tabulated values for those bar sizes are the tension development lengths.
6. Top bars are horizontal bars with more than 300 mm of concrete cast below the bars.
7. For lightweight aggregate concrete, multiply the tabulated values by 1.3.
8. For epoxy-coated bars, if the bar c.-c. spacing is at least 7.0 d_b and the concrete cover is at least 3.0 d_b, then Case 1 lengths may be multiplied by 0.918 (for top bars) or 0.8 (for other bars).

TABLE 19 (CONT.)—TENSION DEVELOPMENT AND LAP SPLICE LENGTHS FOR EPOXY-COATED BARS (ACI 318M, Metric Values)

Bar Size	Lap Class	Lengths (mm) per Concrete Strength (MPa)											
		42 MPa				49 MPa				56 MPa			
		Top Bars		Other Bars		Top Bars		Other Bars		Top Bars		Other Bars	
		Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2
#10	A	510	760	450	670	470	700	410	620	440	660	390	580
	B	660	980	580	870	610	910	540	800	570	850	500	750
#13	A	670	1010	600	890	620	940	550	830	580	880	520	770
	B	880	1310	770	1160	810	1220	720	1070	760	1140	670	1000
#16	A	840	1260	740	1120	780	1170	690	1030	730	1100	650	970
	B	1100	1640	970	1450	1020	1520	900	1340	950	1420	840	1260
#19	A	1010	1520	890	1340	940	1410	830	1240	880	1320	770	1160
	B	1320	1970	1160	1740	1220	1830	1080	1610	1140	1710	1010	1510
#22	A	1470	2200	1300	1950	1360	2040	1200	1800	1270	1910	1120	1690
	B	1910	2860	1690	2530	1770	2650	1560	2340	1660	2480	1460	2190
#25	A	1680	2520	1480	2230	1560	2330	1370	2060	1460	2180	1290	1930
	B	2190	3280	1930	2890	2020	3030	1790	2680	1890	2840	1670	2500
#29	A	1900	2850	1680	2510	1760	2640	1550	2330	1650	2470	1450	2180
	B	2470	3700	2180	3270	2290	3430	2020	3030	2140	3210	1890	2830
#32	A	2140	3210	1890	2830	1980	2970	1750	2620	1850	2780	1630	2450
	B	2780	4170	2450	3680	2570	3860	2270	3400	2410	3610	2120	3180
#36	A	2370	3550	2090	3140	2190	3290	1940	2900	2050	3080	1810	2720
	B	3080	4650	2720	4070	2850	4280	2520	3770	2670	4000	2350	3530
#43	N/A	2850	4270	2510	3770	2630	3950	2320	3490	2460	3700	2180	3260
#57	N/A	3790	5680	3350	5020	3510	5260	3100	4640	3280	4920	2900	4340

Notes:

1. Tabulated values are based on Grade 420 reinforcing bars and normal density concrete. Lengths are in millimeters.
2. Tension development lengths and tension lap splice lengths are calculated per ACI 318M-95, Sections 12.2.2 and 12.15, respectively. Tabulated values for beams or columns are based on transverse reinforcement and concrete cover meeting minimum Code requirements.
3. Cases 1 and 2, which depend on the type of structural element, concrete cover, and the center-to-center spacing of the bars, are defined as:

Beams or Columns:	Case 1:	Cover at least 1.0 d_b **and** c.-c. spacing at least 2.0 d_b
	Case 2:	Cover less than 1.0 d_b **or** c.-c. spacing less than 2.0 d_b
All Others:	Case 1:	Cover at least 1.0 d_b **and** c.-c. spacing at least 3.0 d_b
	Case 2:	Cover less than 1.0 d_b **or** c.-c. spacing less than 3.0 d_b

4. Lap splice lengths are multiples of tension development lengths; Class A = 1.0 ℓ_d and Class B = 1.3 ℓ_d (ACI 318M-95, Section 12.15.1).
5. ACI 318M-95 does not allow tension lap splices of #43 or #57 bars. The tabulated values for those bar sizes are the tension development lengths.
6. Top bars are horizontal bars with more than 300 mm of concrete cast below the bars.
7. For lightweight aggregate concrete, multiply the tabulated values by 1.3.
8. For epoxy-coated bars, if the bar c.-c. spacing is at least 7.0 d_b and the concrete cover is at least 3.0 d_b, then Case 1 lengths may be multiplied by 0.918 (for top bars) or 0.8 (for other bars).

TABLE 20—TENSION DEVELOPMENT AND LAP SPLICE LENGTHS FOR UNCOATED BARS (AASHTO, Metric Values)

Bar Size	Lap Class	Lengths (mm) per Concrete Strength (MPa)											
		24 MPa				28 MPa				35 MPa			
		Top Bars		Other Bars		Top Bars		Other Bars		Top Bars		Other Bars	
		Cat. 1	Cat. 2	Cat. 1	Cat. 2	Cat. 1	Cat. 2	Cat. 1	Cat. 2	Cat. 1	Cat. 2	Cat. 1	Cat. 2
#10	A	300	340	300	300	300	340	300	300	300	340	300	300
	B	350	440	300	310	350	440	300	310	350	440	300	310
	C	460	570	330	410	460	570	330	410	460	570	330	410
#13	A	360	450	300	320	360	450	300	320	360	450	300	320
	B	470	590	340	420	470	590	340	420	470	590	340	420
	C	610	760	440	550	610	760	440	550	610	760	440	550
#16	A	450	560	320	400	450	560	320	400	450	560	320	400
	B	590	730	420	520	590	730	420	520	590	730	420	520
	C	770	960	550	680	770	960	550	680	770	960	550	680
#19	A	550	680	390	490	540	680	390	480	540	680	390	480
	B	710	890	510	640	700	880	500	630	700	880	500	630
	C	930	1160	670	830	920	1150	660	820	920	1150	660	820
#22	A	750	930	530	670	690	860	490	620	630	790	450	560
	B	970	1210	690	870	900	1120	640	800	820	1020	580	730
	C	1270	1580	910	1130	1170	1470	840	1050	1070	1330	760	950
#25	A	980	1230	700	880	910	1140	650	810	810	1020	580	730
	B	1280	1590	910	1140	1180	1480	840	1060	1060	1320	760	940
	C	1670	2080	1190	1490	1540	1930	1100	1380	1380	1730	990	1230
#29	A	1240	1550	890	1110	1150	1440	820	1030	1030	1290	740	920
	B	1610	2020	1150	1440	1490	1870	1070	1330	1340	1670	960	1190
	C	2110	2640	1510	1880	1950	2440	1400	1740	1750	2180	1250	1560
#32	A	1580	1970	1130	1410	1460	1820	1040	1300	1310	1630	930	1170
	B	2050	2560	1460	1830	1900	2370	1360	1690	1700	2120	1210	1510
	C	2680	3350	1910	2390	2480	3100	1770	2210	2220	2770	1580	1980
#36	A	1930	2420	1380	1730	1790	2240	1280	1600	1600	2000	1150	1430
	B	2510	3140	1800	2250	2330	2910	1660	2080	2080	2600	1490	1860
	C	3290	4110	2350	2940	3040	3800	2170	2720	2720	3400	1950	2430
#43	N/A	2400	3000	1720	2150	2230	2780	1590	1990	1990	2490	1420	1780
#57	N/A	3270	4080	2330	2920	3030	3780	2160	2700	2710	3380	1930	2420

Notes:

1. Tabulated values are based on Grade 420 reinforcing bars and normal density concrete. Lengths are in millimeters.
2. Tension development lengths and tension lap splice lengths are calculated per the AASHTO Standard Specifications for Highway Bridges (16th Edition, 1996), Articles 8.25 and 8.32, respectively. Tabulated values for beams or columns are based on transverse reinforcement and concrete cover meeting minimum AASHTO requirements.
3. Categories 1 and 2, which depend on side concrete cover, and the center-to-center spacing of the bars, are defined as:
   Category 1: Side cover at least 75 mm **and** c.-c. spacing at least 150 mm
   Category 2: Side cover less than 75 mm **or** c.-c. spacing less than 150 mm
4. Lap splice lengths are multiples of tension development lengths; Class A = 1.0 ℓ_d, Class B = 1.3 ℓ_d, and Class C = 1.7 ℓ_d. (AASHTO, Article 8.32.3.1).
5. The AASHTO Bridge Specifications do not allow tension lap splices of #43 or #57 bars. The tabulated values for those bar sizes are the tension development lengths.
6. Top bars are horizontal bars with more than 300 mm of concrete cast below the bars.
7. For lightweight aggregate concrete, multiply the tabulated values by 1.33.

TABLE 20 (CONT.)—TENSION DEVELOPMENT AND LAP SPLICE LENGTHS FOR UNCOATED BARS (AASHTO, Metric Values)

Bar Size	Lap Class	Lengths (mm) per Concrete Strength (MPa)											
		42 MPa				49 MPa				56 MPa			
		Top Bars		Other Bars		Top Bars		Other Bars		Top Bars		Other Bars	
		Cat. 1	Cat. 2	Cat. 1	Cat. 2	Cat. 1	Cat. 2	Cat. 1	Cat. 2	Cat. 1	Cat. 2	Cat. 1	Cat. 2
#10	A	300	340	300	300	300	340	300	300	300	340	300	300
	B	350	440	300	310	350	440	300	310	350	440	300	310
	C	460	570	330	410	460	570	330	410	460	570	330	410
#13	A	360	450	300	320	360	450	300	320	360	450	300	320
	B	470	590	340	420	470	590	340	420	470	590	340	420
	C	610	760	440	550	610	760	440	550	610	760	440	550
#16	A	450	560	320	400	450	560	320	400	450	560	320	400
	B	590	730	420	520	590	730	420	520	590	730	420	520
	C	770	960	550	680	770	960	550	680	770	960	550	680
#19	A	540	680	390	480	540	680	390	480	540	680	390	480
	B	700	880	500	630	700	880	500	630	700	880	500	630
	C	920	1150	660	820	920	1150	660	820	920	1150	660	820
#22	A	630	790	450	560	630	790	450	560	630	790	450	560
	B	820	1020	580	730	820	1020	580	730	820	1020	580	730
	C	1070	1330	760	950	1070	1330	760	950	1070	1330	760	950
#25	A	740	930	530	660	720	900	520	640	720	900	520	640
	B	970	1210	690	860	930	1170	670	840	930	1170	670	840
	C	1260	1580	900	1130	1220	1530	870	1090	1220	1530	870	1090
#29	A	940	1170	670	840	870	1090	620	780	810	1020	580	730
	B	1220	1520	870	1090	1130	1410	810	1010	1060	1320	760	940
	C	1590	1990	1140	1420	1480	1850	1060	1320	1380	1730	990	1230
#32	A	1190	1490	850	1060	1100	1380	790	990	1030	1290	740	920
	B	1550	1940	1110	1380	1430	1790	1030	1280	1340	1680	960	1200
	C	2020	2530	1450	1810	1870	2340	1340	1670	1750	2190	1250	1570
#36	A	1460	1830	1050	1310	1360	1690	970	1210	1270	1580	910	1130
	B	1900	2380	1360	1700	1760	2200	1260	1570	1650	2060	1180	1470
	C	2490	3110	1780	2220	2300	2880	1640	2060	2150	2690	1540	1920
#43	N/A	1820	2270	1300	1620	1680	2100	1200	1500	1570	1970	1130	1410
#57	N/A	2470	3090	1770	2210	2290	2860	1630	2040	2140	2670	1530	1910

Notes:

1. Tabulated values are based on Grade 420 reinforcing bars and normal density concrete. Lengths are in millimeters.
2. Tension development lengths and tension lap splice lengths are calculated per the AASHTO Standard Specifications for Highway Bridges (16th Edition, 1996), Articles 8.25 and 8.32, respectively. Tabulated values for beams or columns are based on transverse reinforcement and concrete cover meeting minimum AASHTO requirements.
3. Categories 1 and 2, which depend on side concrete cover, and the center-to-center spacing of the bars, are defined as:
   Category 1: Side cover at least 75 mm **and** c.-c. spacing at least 150 mm
   Category 2: Side cover less than 75 mm **or** c.-c. spacing less than 150 mm
4. Lap splice lengths are multiples of tension development lengths: Class A = 1.0 ℓ_d, Class B = 1.3 ℓ_d, and Class C = 1.7 ℓ_d (AASHTO, Article 8.32.3.1).
5. The AASHTO Bridge Specifications do not allow tension lap splices of #43 or #57 bars. The tabulated values for those bar sizes are the tension development lengths.
6. Top bars are horizontal bars with more than 300 mm of concrete cast below the bars.
7. For lightweight aggregate concrete, multiply the tabulated values by 1.33.

TABLE 21—TENSION DEVELOPMENT AND LAP SPLICE LENGTHS FOR EPOXY-COATED BARS (AASHTO, Metric Values)

Bar Size	Lap Class	Lengths (mm) per Concrete Strength (MPa)											
		24 MPa				28 MPa				35 MPa			
		Top Bars		Other Bars		Top Bars		Other Bars		Top Bars		Other Bars	
		Cat. 1	Cat. 2	Cat. 1	Cat. 2	Cat. 1	Cat. 2	Cat. 1	Cat. 2	Cat. 1	Cat. 2	Cat. 1	Cat. 2
#10	A	330	410	300	360	330	410	300	360	330	410	300	360
	B	430	530	380	470	430	530	380	470	430	530	380	470
	C	560	690	490	610	560	690	490	610	560	690	490	610
#13	A	440	550	390	480	440	550	390	480	440	550	390	480
	B	570	710	500	630	570	710	500	630	570	710	500	630
	C	740	930	660	820	740	930	660	820	740	930	660	820
#16	A	550	680	480	600	550	680	480	600	550	680	480	600
	B	710	890	630	780	710	890	630	780	710	890	630	780
	C	930	1160	820	1020	930	1160	820	1020	930	1160	820	1020
#19	A	670	830	590	730	660	820	580	720	660	820	580	720
	B	860	1080	760	950	850	1070	750	940	850	1070	750	940
	C	1130	1410	1000	1240	1120	1390	980	1230	1120	1390	980	1230
#22	A	910	1130	800	1000	840	1050	740	920	760	950	670	840
	B	1180	1470	1040	1300	1090	1360	960	1200	990	1240	880	1090
	C	1540	1920	1360	1700	1420	1780	1260	1570	1300	1620	1140	1430
#25	A	1190	1490	1050	1310	1100	1380	970	1220	990	1230	870	1090
	B	1550	1940	1370	1710	1430	1790	1270	1580	1280	1600	1130	1420
	C	2020	2530	1790	2230	1870	2340	1650	2070	1680	2100	1480	1850
#29	A	1510	1880	1330	1660	1400	1740	1230	1540	1250	1560	1100	1380
	B	1960	2450	1730	2160	1810	2270	1600	2000	1620	2030	1430	1790
	C	2560	3200	2260	2820	2370	2960	2090	2610	2120	2650	1870	2340
#32	A	1910	2390	1690	2110	1770	2210	1560	1950	1580	1980	1400	1750
	B	2490	3110	2190	2740	2300	2880	2030	2540	2060	2570	1820	2270
	C	3250	4060	2870	3580	3010	3760	2660	3320	2690	3360	2380	2970
#36	A	2350	2940	2070	2590	2170	2720	1920	2400	1950	2430	1720	2150
	B	3050	3820	2690	3370	2830	3530	2490	3120	2530	3160	2230	2790
	C	3990	4990	3520	4400	3700	4620	3260	4080	3310	4130	2920	3650
#43	N/A	2920	3650	2570	3220	2700	3380	2380	2980	2420	3020	2130	2670
#57	N/A	3970	4960	3500	4380	3670	4590	3240	4050	3290	4110	2900	3620

Notes:

1. Tabulated values are based on Grade 420 reinforcing bars and normal density concrete. Lengths are in millimeters.
2. Tension development lengths and tension lap splice lengths are calculated per the AASHTO Standard Specifications for Highway Bridges (16th Edition, 1996), Articles 8.25 and 8.32, respectively. Tabulated values for beams or columns are based on transverse reinforcement and concrete cover meeting minimum AASHTO requirements.
3. Categories 1 and 2, which depend on side concrete cover, and the center-to-center spacing of the bars, are defined as:
   Category 1: Side cover at least 75 mm **and** c.-c. spacing at least 150 mm
   Category 2: Side cover less than 75 mm **or** c.-c. spacing less than 150 mm
4. Lap splice lengths are multiples of tension development lengths: Class A = 1.0 ℓ_d, Class B = 1.3 ℓ_d and Class C = 1.7 ℓ_d (AASHTO, Article 8.32.3.1).
5. The AASHTO Bridge Specifications do not allow lap splices of #43 or #57 bars. The tabulated values for those bar sizes are the tension development lengths.
6. Top bars are horizontal bars with more than 300 mm of concrete cast below the bars.
7. For lighweight aggregate concrete, multiply the tabulated values by 1.33.
8. For epoxy-coated bars, if the bar c.-c. spacing is at least 7.0 d_b and the concrete cover is at least 3.0 d_b, then Category 1 lengths may be multiplied by 0.947 (for top bars or 0.767 (for other bars).

TABLE 21 (CONT.)—TENSION DEVELOPMENT AND LAP SPLICE LENGTHS FOR EPOXY-COATED BARS (AASHTO, Metric Values)

Bar Size	Lap Class	Lengths (mm) per Concrete Strength (MPa)											
		42 MPa				49 MPa				56 MPa			
		Top Bars		Other Bars		Top Bars		Other Bars		Top Bars		Other Bars	
		Cat. 1	Cat. 2	Cat. 1	Cat. 2	Cat. 1	Cat. 2	Cat. 1	Cat. 2	Cat. 1	Cat. 2	Cat. 1	Cat. 2
#10	A	330	410	300	360	330	410	300	360	330	410	300	360
	B	430	530	380	470	430	530	380	470	430	530	380	470
	C	560	690	490	610	560	690	490	610	560	690	490	610
#13	A	440	550	390	480	440	550	390	480	440	550	390	480
	B	570	710	500	630	570	710	500	630	570	710	500	630
	C	740	930	660	820	740	930	660	820	740	930	660	820
#16	A	550	680	480	600	550	680	480	600	550	680	480	600
	B	710	890	630	780	710	890	630	780	710	890	630	780
	C	930	1160	820	1020	930	1160	820	1020	930	1160	820	1020
#19	A	660	820	580	720	660	820	580	720	660	820	580	720
	B	850	1070	750	940	850	1070	750	940	850	1070	750	940
	C	1120	1390	980	1230	1120	1390	980	1230	1120	1390	980	1230
#22	A	760	950	670	840	760	950	670	840	760	950	670	840
	B	990	1240	880	1090	990	1240	880	1090	990	1240	880	1090
	C	1300	1620	1140	1430	1300	1620	1140	1430	1300	1620	1140	1430
#25	A	900	1130	800	990	870	1090	770	960	870	1090	770	960
	B	1170	1460	1030	1290	1130	1420	1000	1250	1130	1420	1000	1250
	C	1530	1910	1350	1690	1480	1850	1310	1640	1480	1850	1310	1640
#29	A	1140	1420	1010	1260	1060	1320	930	1160	990	1230	870	1090
	B	1480	1850	1310	1630	1370	1710	1210	1510	1280	1600	1130	1410
	C	1940	2420	1710	2130	1790	2240	1580	1980	1680	2100	1480	1850
#32	A	1450	1810	1280	1600	1340	1670	1180	1480	1250	1570	1110	1380
	B	1880	2350	1660	2070	1740	2170	1540	1920	1630	2030	1440	1800
	C	2460	3070	2170	2710	2280	2840	2010	2510	2130	2660	1880	2350
#36	A	1780	2220	1570	1960	1640	2060	1450	1810	1540	1920	1360	1700
	B	2310	2880	2040	2550	2140	2670	1890	2360	2000	2500	1760	2210
	C	3020	3770	2660	3330	2790	3490	2470	3080	2610	3270	2310	2880
#43	N/A	2210	2760	1950	2430	2040	2550	1800	2250	1910	2390	1690	2110
#57	N/A	3000	3750	2650	3310	2780	3470	2450	3060	2600	3250	2290	2870

Notes:

1. Tabulated values are based on Grade 420 reinforcing bars and normal density concrete. Lengths are in millimeters.
2. Tension development lengths and tension lap splice lengths are calculated per the AASHTO Standard Specifications for Highway Bridges (16th Edition, 1996), Articles 8.25 and 8.32, respectively. Tabulated values for beams or columns are based on transverse reinforcement and concrete cover meeting minimum AASHTO requirements
3. Categories 1 and 2, which depend on side concrete cover, and the center-to-center spacing of the bars, are defined as:
   Category 1: Side cover at least 75 mm **and** c.-c. spacing at least 150 mm
   Category 2: Side cover less than 75 mm **or** c.-c. spacing less than 150 mm
4. Lap splice lengths are multiples of tension development lengths; Class A = 1.0 ℓ_d, Class B = 1.3 ℓ_d and Class C = 1.7 ℓ_d (AASHTO, Article 8.32.3.1).
5. The AASHTO Bridge Specifications do not allow lap splices of #43 or #57 bars. The tabulated values for those bar sizes are the tension development lengths.
6. Top bars are horizontal bars with more than 300 mm of concrete cast below the bars.
7. For lightweight aggregate concrete, multiply the tabulated values by 1.33.
8. For epoxy-coated bars, if the bar c.-c. spacing is at least 7.0 d_b and the concrete cover is at least 3.0 d_b, then Category 1 lengths may be multiplied by 0.947 (for top bars) or 0.767 (for other bars)

TABLE 22—TENSION DEVELOPMENT AND LAP SPLICE LENGTHS FOR BARS IN WALLS AND SLABS (ACI 318M, Metric Values)

f'_c = 21 MPa

Bar Size	Lap Class	Concrete Cover = 20 mm				Concrete Cover = 25 mm				Concrete Cover = 40 mm				Concrete Cover = 50 mm			
		Uncoated		Epoxy-Coated		Uncoated		Epoxy-Coated		Uncoated		Epoxy-Coated		Uncoated		Epoxy-Coated	
		Top	Other	Top	Other	Top	Other	Top	Other	Top	Other	Top	Other	Top	Other	Top	Other
#10	A	410	320	540	470	410	320	540	470	410	320	490	380	410	320	490	380
	B	530	410	700	610	530	410	700	610	530	410	640	490	530	410	640	490
#13	A	660	510	860	760	550	430	720	640	550	420	660	510	550	420	660	510
	B	860	660	1120	990	720	550	940	830	710	550	850	660	710	550	850	660
#16	A	970	750	1270	1120	830	640	1080	950	680	530	890	790	680	530	820	630
	B	1260	970	1650	1460	1070	830	1400	1240	890	680	1160	1030	890	680	1070	820
#19	A	1330	1020	1730	1530	1140	870	1480	1310	820	630	1070	950	820	630	1070	950
	B	1720	1330	2250	1990	1470	1140	1930	1700	1070	820	1400	1230	1070	820	1400	1230
#22	A	1700	1310	2230	1960	1470	1130	1920	1690	1040	800	1360	1200	960	740	1250	1100
	B	2210	1700	2890	2550	1910	1470	2490	2200	1350	1040	1760	1550	1240	960	1620	1430
#25	A	2120	1630	2770	2440	1840	1410	2400	2120	1320	1010	1720	1520	1110	850	1450	1280
	B	2750	2120	3600	3180	2390	1840	3120	2760	1710	1320	2230	1970	1440	1110	1880	1660
#29	A	2570	1980	3370	2970	2250	1730	2940	2590	1630	1250	2130	1880	1380	1060	1800	1590
	B	3350	2570	4370	3860	2920	2250	3820	3370	2120	1630	2770	2440	1790	1380	2340	2060
#32	A	3100	2380	4050	3570	2720	2090	3560	3140	2000	1540	2610	2300	1690	1300	2210	1950
	B	4030	3100	5260	4650	3540	2720	4620	4080	2590	2000	3390	2990	2200	1690	2880	2540
#36	A	3630	2790	4740	4190	3210	2470	4190	3700	2380	1830	3110	2740	2030	1560	2650	2340
	B	4720	3630	6170	5440	4170	3210	5450	4810	3090	2380	4040	3560	2630	2030	3440	3040

Notes:

1. Tabulated values are based on Grade 420 reinforcing bars and normal density concrete. Lengths are in millimeters.
2. Tension development lengths and tension lap splice lengths are calculated per ACI 318M-95, Sections 12.2.3 and 12.15, respectively.
3. Lap splice lengths are multiples of tension development lengths: Class A = 1.0 ℓ_d and Class B = 1.3 ℓ_d (ACI 318M-95, Section 12.15.1).
4. Bar sizes in this table were restricted to typical sizes for walls and slabs.
5. Top bars are horizontal bars with more than 300 mm of concrete cast below the bars.
6. For lightweight aggregate concrete, multiply the tabulated values by 1.3

TABLE 23—TENSION DEVELOPMENT AND LAP SPLICE LENGTHS FOR BARS IN WALLS AND SLABS (ACI 318M, Metric Values)

f'_c = 28 MPa

Bar Size	Lap Class	Concrete Cover = 20 mm				Concrete Cover = 25 mm				Concrete Cover = 40 mm				Concrete Cover = 50 mm			
		Uncoated		Epoxy-Coated		Uncoated		Epoxy-Coated		Uncoated		Epoxy-Coated		Uncoated		Epoxy-Coated	
		Top	Other	Top	Other	Top	Other	Top	Other	Top	Other	Top	Other	Top	Other	Top	Other
#10	A	360	300	460	410	360	300	460	410	360	300	430	330	360	300	430	330
	B	460	390	600	530	460	390	600	530	460	390	550	430	460	390	550	430
#13	A	570	440	750	660	480	370	630	550	470	370	570	440	470	370	570	440
	B	740	570	970	860	620	480	820	720	620	470	740	570	620	470	740	570
#16	A	840	650	1100	970	720	550	930	830	590	460	780	680	590	460	710	550
	B	1090	840	1430	1260	930	720	1210	1070	770	590	1010	890	770	590	920	710
#19	A	1150	880	1500	1330	980	760	1290	1130	710	550	930	820	710	550	930	820
	B	1490	1150	1950	1720	1280	980	1670	1470	930	710	1210	1070	930	710	1210	1070
#22	A	1470	1140	1930	1700	1270	980	1660	1470	900	690	1170	1040	830	640	1080	950
	B	1920	1470	2500	2210	1650	1270	2160	1900	1170	900	1530	1350	1080	830	1400	1240
#25	A	1840	1410	2400	2120	1590	1230	2080	1840	1140	880	1490	1310	960	740	1250	1110
	B	2380	1840	3120	2750	2070	1590	2700	2390	1480	1140	1940	1710	1250	960	1630	1440
#29	A	2230	1720	2920	2570	1950	1500	2550	2250	1410	1090	1840	1630	1190	920	1560	1370
	B	2900	2230	3790	3340	2530	1950	3310	2920	1830	1410	2400	2110	1550	1190	2020	1790
#32	A	2680	2060	3510	3100	2360	1810	3080	2720	1730	1330	2260	1990	1470	1130	1920	1690
	B	3490	2680	4560	4020	3060	2360	4010	3530	2250	1730	2940	2590	1910	1470	2490	2200
#36	A	3140	2420	4110	3630	2780	2140	3630	3200	2060	1580	2690	2370	1760	1350	2300	2030
	B	4090	3140	5340	4710	3610	2780	4720	4160	2680	2060	3500	3090	2280	1760	2980	2630

Notes:

1. Tabulated values are based on Grade 420 reinforcing bars and normal density concrete. Lengths are in millimeters.
2. Tension development lengths and tension lap splice lengths are calculated per ACI 318M-95, Sections 12.2.3 and 12.15, respectively.
3. Lap splice lengths are multiples of tension development lengths; Class A = 1.0 ℓ_d and Class B = 1.3 ℓ_d (ACI 318M-95, Section 12.15.1).
4. Bar sizes in this table were restricted to typical sizes for walls and slabs.
5. Top bars are horizontal bars with more than 300 mm of concrete cast below the bars.
6. For lightweight aggregate concrete, multiply the tabulated values by 1.3.

TABLE 24—TENSION DEVELOPMENT LENGTHS FOR UNCOATED BARS IN SEISMIC JOINTS (ACI 318M, Metric Values)

Bar Size	Lengths (mm) per Concrete Strength (MPa)											
	21 MPa		28 MPa		35 MPa		42 MPa		49 MPa		56 MPa	
	Top	Other	Top	Other	Top	Other	Top	Other	Top	Other	Top	Other
#10	570	410	530	380	530	380	530	380	530	380	530	380
#13	760	540	660	470	590	420	540	380	530	380	530	380
#16	950	680	820	590	730	530	670	480	620	440	580	420
#19	1140	810	990	700	880	630	810	580	750	530	700	500
#22	1320	940	1150	820	1020	730	940	670	870	620	810	580
#25	1510	1080	1310	940	1170	840	1070	770	990	710	930	660
#29	1710	1220	1480	1060	1320	950	1210	860	1120	800	1050	750
#32	1920	1370	1660	1190	1490	1060	1360	970	1260	900	1180	840
#36	2130	1520	1840	1320	1650	1180	1510	1080	1400	1000	1310	930

Notes:

1. Tabulated values are based on Grade 420 reinforcing bars and normal density concrete. Lengths are in millimeters.
2. Tension development lengths are calculated per ACI 318M-95, Section 21.5.4.2, where bar sizes are limited to #10 through #36 only.
3. Top bars are horizontal bars with more than 300 mm of concrete cast below the bars.

TABLE 25—TENSION DEVELOPMENT LENGTHS FOR EPOXY-COATED BARS IN SEISMIC JOINTS (ACI 318, Metric Values)

Bar Size	Lengths (mm) per Concrete Strength (MPa)											
	21 MPa		28 MPa		35 MPa		42 MPa		49 MPa		56 MPa	
	Top	Other	Top	Other	Top	Other	Top	Other	Top	Other	Top	Other
#10	690	610	640	570	640	570	640	570	640	570	640	570
#13	920	810	800	700	710	630	650	570	640	570	640	570
#16	1150	1010	1000	880	890	790	810	720	750	670	710	620
#19	1380	1220	1200	1060	1070	940	980	860	900	800	850	750
#22	1600	1420	1390	1230	1240	1100	1140	1000	1050	930	980	870
#25	1840	1620	1590	1400	1420	1260	1300	1150	1200	1060	1120	990
#29	2070	1830	1800	1580	1610	1420	1470	1290	1360	1200	1270	1120
#32	2330	2060	2020	1780	1810	1600	1650	1460	1530	1350	1430	1260
#36	2590	2280	2240	1980	2000	1770	1830	1610	1690	1490	1580	1400

Notes:

1. Tabulated values are based on Grade 420 reinforcing bars and normal density concrete. Lengths are in millimeters.
2. Tension development lengths are calculated per ACI 318M-95, Section 21.5.4.2, where bar sizes are limited to #10 through #36 only.
3. Top bars are horizontal bars with more than 300 mm of concrete cast below the bars.

TABLE 26—TENSION DEVELOPMENT LENGTHS OF STANDARD HOOKS FOR UNCOATED BARS (ACI 318M and AASHTO, Metric Values)

Bar Size	Length (mm) per Concrete Strength (MPa)						
	21 MPa	24 MPa	28 MPa	35 MPa	42 MPa	49 MPa	56 MPa
#10	210	200	180	160	150	150	150
#13	280	260	240	220	200	180	170
#16	350	330	300	270	250	230	220
#19	420	390	360	330	300	280	260
#22	490	460	420	380	350	320	300
#25	560	520	480	430	390	370	340
#29	630	590	550	490	450	410	390
#32	710	660	610	550	500	460	430
#36	780	730	680	610	560	510	480
#43	940	880	820	730	670	620	580
#57	1250	1170	1090	970	890	820	770

Notes:

1. Tabulated values are based on Grade 420 reinforcing bars and normal density concrete. Lengths are in millimeters.
2. Tension development lengths of standard hooks are calculated per ACI 318M-95, Section 12.5 and the AASHTO Bridge Specifications for Highway Bridges (16th Edition, 1996), Article 8.29.
3. For bar sizes #10 through #36 only:
   a. If concrete cover conforms to ACI 318M-95 (Section 12.5.3.3) or AASHTO (Article 8.29.3.2), then a modification factor of 0.7 may be applied but the length must not be less than 8.0 d_b nor 150 mm.
   b. If hook is enclosed in ties or stirrups per ACI 318M-95 (Section 12.5.3.3) or AASHTO (Article 8.29.3.3), then a modification factor of 0.8 may be applied but the length must not be less than 8.0 d_b nor 150 mm.
4. For lightweight aggregate concrete, multiply the tabulated values by 1.3.

TABLE 27—TENSION DEVELOPMENT LENGTHS OF STANDARD HOOKS FOR EPOXY-COATED BARS (ACI 318M and AASHTO, Metric Values)

Bar Size	Length (mm) per Concrete Strength (MPa)						
	21 MPa	24 MPa	28 MPa	35 MPa	42 MPa	49 MPa	56 MPa
#10	250	240	220	200	180	170	160
#13	340	310	290	260	240	220	210
#16	420	390	360	330	300	280	260
#19	500	470	440	390	360	330	310
#22	580	550	510	450	410	380	360
#25	670	630	580	520	470	440	410
#29	750	710	650	590	530	500	460
#32	850	790	740	660	600	560	520
#36	940	880	810	730	670	620	580
#43	1130	1060	980	880	800	740	690
#57	1500	1410	1300	1170	1060	990	920

Notes:

1. Tabulated values are based on Grade 420 reinforcing bars and normal density concrete. Lengths are in millimeters.
2. Tension development lengths of standard hooks are calculated per ACI 318M-95, Section 12.5 and the AASHTO Bridge Specifications for Highway Bridges (16th Edition, 1996), Article 8.29.
3. For bar sizes #10 through #36 only.
   a. If concrete cover conforms to ACI 318M-95 (Section 12.5.3.3) or AASHTO (Article 8.29.3.2), then a modification factor of 0.7 may be applied but the length must not be less than 8.0 d_b nor 150 mm.
   b. If hook is enclosed in ties or stirrups per ACI 318M-95 (Section 12.5.3.3) or AASHTO (Article 8.29.3.3), then a modification factor of 0.8 may be applied but the length must not be less than 8.0 d_b nor 150 mm.
4. For lightweight aggregate concrete, multiply the tabulated values by 1.3

TABLE 28—TENSION DEVELOPMENT LENGTHS OF STANDARD HOOKS FOR UNCOATED BARS IN SEISMIC JOINTS (ACI 318M Metric Values)

Bar Size	Lengths (mm) per Concrete Strengths (MPa)					
	21 MPa	28 MPa	35 MPa	42 MPa	49 MPa	56 MPa
#10	160	150	150	150	150	150
#13	220	190	170	160	150	150
#16	270	240	210	190	180	170
#19	330	280	250	230	220	200
#22	380	330	290	270	250	230
#25	430	380	340	310	290	270
#29	490	420	380	350	320	300
#32	550	480	430	390	360	340
#36	610	530	470	430	400	380

Notes:
1. Tabulated values are based on Grade 420 reinforcing bars and normal density concrete. Lengths are in millimeters.
2. Tension development lengths of standard hooks are calculated per ACI 318M-95, Section 21.5.4.1, where bar sizes are limited to #10 through #36 only.

TABLE 29—TENSION DEVELOPMENT LENGTHS OF STANDARD HOOKS FOR EPOXY-COATED BARS IN SEISMIC JOINTS (ACI 318M Metric Values)

Bar Size	Lengths (mm) per Concrete Strengths (MPa)					
	21 MPa	28 MPa	35 MPa	42 MPa	49 MPa	56 MPa
#10	200	180	180	180	180	180
#13	260	230	200	190	180	180
#16	330	280	250	230	210	200
#19	390	340	300	280	260	240
#22	460	390	350	320	300	280
#25	520	450	400	370	340	320
#29	590	510	460	420	390	360
#32	660	570	510	470	430	410
#36	730	630	570	520	480	450

Notes:
1. Tabulated values are based on Grade 420 reinforcing bars and normal density concrete. Lengths are in millimeters.
2. Tension development lengths of standard hooks are calculated per ACI 318M-95, Section 21.5.4.1, where bar sizes are limited to #10 through #36 only.

TABLE 30—COMPRESSION DEVELOPMENT AND LAP SPLICE LENGTHS FOR UNCOATED AND EPOXY-COATED BARS (ACI 318M and AASHTO, Metric Values)

Bar Size	Compression Length (mm) per Concrete Strength (MPa)							Lap Splice
	21 MPa	24 MPa	28 MPa	35 MPa	42 MPa	49 MPa	56 MPa	
#10	220	210	200	200	200	200	200	300
#13	290	280	260	230	220	220	220	380
#16	370	340	320	290	270	270	270	470
#19	440	410	380	340	320	320	320	560
#22	510	480	440	400	380	380	380	660
#25	580	550	510	450	430	430	430	750
#29	660	620	570	510	490	490	490	850
#32	740	700	640	580	550	550	550	950
#36	820	770	710	640	600	600	600	1060
#43	990	920	860	770	730	730	730	N/A
#57	1320	1230	1140	1020	970	970	970	N/A

Notes:

1. Tabulated values are based on Grade 420 reinforcing bars and normal density concrete. Lengths are in millimeters.
2. Compression development lengths are calculated per ACI 318M-95, Section 12.3, and AASHTO Standard Specifications for Highway Bridges (16th Edition, 1996), Article 8.26. Compression lap splice lengths are calculated per ACI 318M-95, Section 12.16, and AASHTO Standard Specifications for Highway Bridges (16th Edition, 1996), Article 8.32.4.
3. For compression development lengths, if bars are enclosed in spirals or ties per ACI 318M-95, Section 12.3.3.2, or AASHTO, Article 8.26.2.2, then a modification factor of 0.75 may be applied but the length must not be less than 200 mm.
4. For compression lap splice lengths:
   a. If bars are enclosed in a tied compression member per ACI 318M-95, Section 12.17.2.4, or AASHTO, Article 8.32.4.1, then a modification factor of 0.83 may be applied but the length must not be less than 300 mm.
   b. If bars are enclosed in a spirally-reinforced compression member per ACI 318M-95, Section 12.17.2.5, or AASHTO, Article 8.32.4.1, then a modification factor of 0.75 may be applied but the length must not be less than 300 mm.
5. ACI 318M-95 and AASHTO do not allow compression lap splices of #43 and #57 bars, except to #36 and smaller bars.

TABLE 31—TENSION DEVELOPMENT AND LAP SPLICE LENGTHS FOR DEFORMED WIRE
f'_c = 28 MPa (ACI 318M, Metric Values)

Wire Size	Development Length (mm)		Lap Splice Length, mm (Class B)	
	Top	Other	Top	Other
MD-7	300	300	390	390
MD-13	300	300	390	390
MD-19	300	300	390	390
MD-26	350	300	450	390
MD-32	390	300	510	390
MD-39	430	330	550	430
MD-45	460	350	600	460
MD-52	490	380	640	490
MD-58	520	400	680	520
MD-65	550	420	720	550
MD-71	580	440	750	580
MD-77	600	460	780	600
MD-84	630	480	820	630
MD-90	650	500	850	650
MD-97	670	520	880	670
MD-103	700	540	910	700
MD-110	720	550	930	720
MD-116	740	570	960	740
MD-123	760	580	990	760
MD-129	780	600	1010	780
MD-136	800	610	1040	800
MD-142	820	630	1060	820
MD-148	830	640	1090	830
MD-155	850	660	1110	850
MD-161	870	670	1130	870
MD-168	890	680	1150	890
MD-174	900	700	1180	900
MD-181	920	710	1200	920
MD-187	940	720	1220	940
MD-194	950	730	1240	950
MD-200	970	750	1260	970
MD-290	1170	900	1520	1170

Notes:

1. Tabulated values are based on a minimum yield strength of 515 MPa and 28 MPa normal density concrete. Lengths are in millimeters.
2. Tension development lengths and tension lap splice lengths are calculated per ACI 318M-95, Sections 12.2.2 and 12.15, respectively.
3. Lap splice lengths are multiples of tension development lengths; Class A = 1.0 ℓ_d and Class B = 1.3 ℓ_d (ACI 318M-95, Section 12.15.1). Lap Class B was assumed for the tables.
4. Top wires are horizontal wires with more than 300 mm of concrete cast below the wires.
5. For lightweight aggregate concrete, multiply the tabulated values by 1.3.

TABLE 32—TENSION DEVELOPMENT LENGTHS FOR DEFORMED WELDED WIRE FABRIC
(ACI 318M, Metric Values)

f'_c = 28 MPa

Wire Size	For Top WWF per Wire Spacing (mm)				For Other WWF per Wire Spacing (mm)			
	102	152	203	305	102	152	203	305
MD-7	100	100	100	100	100	100	100	100
MD-13	120	120	120	120	100	100	100	100
MD-19	140	140	140	140	110	110	110	110
MD-26	170	170	170	170	130	130	130	130
MD-32	190	190	190	190	140	140	140	140
MD-39	200	200	200	200	160	160	160	160
MD-45	220	220	220	220	170	170	170	170
MD-52	230	230	230	230	180	180	180	180
MD-58	250	250	250	250	190	190	190	190
MD-65	260	260	260	260	200	200	200	200
MD-71	270	270	270	270	210	210	210	210
MD-77	290	290	290	290	220	220	220	220
MD-84	300	300	300	300	230	230	230	230
MD-90	320	310	310	310	250	240	240	240
MD-97	350	320	320	320	270	250	250	250
MD-103	370	330	330	330	280	250	250	250
MD-110	390	340	340	340	300	260	260	260
MD-116	410	350	350	350	320	270	270	270
MD-123	440	360	360	360	340	280	280	280
MD-129	460	370	370	370	350	280	280	280
MD-136	480	380	380	380	370	290	290	290
MD-142	510	390	390	390	390	300	300	300
MD-148	530	400	400	400	410	310	310	310
MD-155	550	410	410	410	430	310	310	310
MD-161	580	410	410	410	440	320	320	320
MD-168	600	420	420	420	460	320	320	320
MD-174	620	430	430	430	480	330	330	330
MD-181	640	440	440	440	500	340	340	340
MD-187	670	450	450	450	510	340	340	340
MD-194	690	460	450	450	530	360	350	350
MD-200	710	480	460	460	550	370	350	350
MD-290	1040	700	560	560	800	530	430	430

Notes:

1. Tabulated values are based on a minimum yield strength of 485 MPa and 28 MPa normal density concrete. Lengths are in millimeters.
2. Tension development lengths are calculated per ACI 318M-95, Section 12.7.
3. Top WWF is horizontal WWF with more than 300 mm of concrete cast below the WWF.
4. For lightweight aggregate concrete, multiply the tabulated values by 1.3.

TABLE 33—TENSION LAP SPLICE LENGTHS FOR DEFORMED WELDED WIRE FABRIC (ACI 318M, Metric Values)

f'_c = 28 MPa

Wire Size	For Top WWF per Wire Spacing (mm)				For Other WWF per Wire Spacing (mm)			
	102	152	203	305	102	152	203	305
MD-7	200	200	200	200	200	200	200	200
MD-13	200	200	200	200	200	200	200	200
MD-19	200	200	200	200	200	200	200	200
MD-26	220	220	220	220	200	200	200	200
MD-32	240	240	240	240	200	200	200	200
MD-39	260	260	260	260	200	200	200	200
MD-45	280	280	280	280	220	220	220	220
MD-52	300	300	300	300	230	230	230	230
MD-58	320	320	320	320	250	250	250	250
MD-65	340	340	340	340	260	260	260	260
MD-71	360	360	360	360	270	270	270	270
MD-77	370	370	370	370	290	290	290	290
MD-84	390	390	390	390	300	300	300	300
MD-90	420	400	400	400	320	310	310	310
MD-97	450	420	420	420	350	320	320	320
MD-103	480	430	430	430	370	330	330	330
MD-110	510	440	440	440	390	340	340	340
MD-116	540	460	460	460	410	350	350	350
MD-123	570	470	470	470	440	360	360	360
MD-129	600	480	480	480	460	370	370	370
MD-136	630	490	490	490	480	380	380	380
MD-142	660	500	500	500	510	390	390	390
MD-148	690	520	520	520	530	400	400	400
MD-155	720	530	530	530	550	410	410	410
MD-161	750	540	540	540	580	410	410	410
MD-168	780	550	550	550	600	420	420	420
MD-174	810	560	560	560	620	430	430	430
MD-181	840	570	570	570	640	440	440	440
MD-187	870	580	580	580	670	450	450	450
MD-194	900	600	590	590	690	460	450	450
MD-200	930	620	600	600	710	480	460	460
MD-290	1350	900	720	720	1040	700	560	560

Notes:

1. Tabulated values are based on a minimum yield strength of 485 MPa and 28 MPa normal density concrete. Lengths are in millimeters.
2. Tension lap splice lengths are calculated per ACI 318M-95, Section 12.18
3. Top WWF is horizontal WWF with more than 300 mm of concrete cast below the WWF.
5. For lightweight aggregate concrete, multiply the tabulated values by 1.3

TABLE 34—TENSION DEVELOPMENT AND LAP SPLICE LENGTHS FOR PLAIN WELDED WIRE FABRIC
(ACI 318M, Metric Values)

$f'_c = 28$ MPa

Wire Size	Wire Spacing	Development Length (mm) per Cross Wire Spacing (mm)				Lap Splice Length (mm) per Cross Wire Spacing (mm)			
		102	152	203	305	102	152	203	305
MW3	102	150	150	150	150	150	150	210	310
to	152	150	150	150	150	150	150	210	310
MW 36	305	150	150	150	150	150	150	210	310
MW39	102	150	150	150	150	160	160	210	310
	152	150	150	150	150	150	150	210	310
	305	150	150	150	150	150	150	210	310
MW52	102	150	150	150	150	210	210	210	310
	152	150	150	150	150	150	150	210	310
	305	150	150	150	150	150	150	210	310
MW65	102	180	180	180	180	270	270	270	310
	152	150	150	150	150	180	180	210	310
	305	150	150	150	150	150	150	210	310
MW77	102	210	210	210	210	320	320	320	320
	152	150	150	150	150	210	210	210	310
	305	150	150	150	150	150	150	210	310
MW90	102	250	250	250	250	370	370	370	370
	152	170	170	170	170	250	250	250	310
	305	150	150	150	150	150	150	210	310
MW103	102	280	280	280	280	430	430	430	430
	152	190	190	190	190	290	290	290	310
	305	150	150	150	150	150	150	210	310
MW116	102	320	320	320	320	480	480	480	480
	152	210	210	210	210	320	320	320	320
	305	150	150	150	150	160	160	210	310
MW129	102	360	360	350	360	530	530	530	530
	152	240	240	240	240	360	360	360	360
	305	150	150	150	150	180	180	210	310
MW142	102	390	390	390	390	590	590	590	590
	152	260	260	260	260	390	390	390	390
	305	150	150	150	150	200	200	210	310
MW155	102	430	430	430	430	640	640	640	640
	152	290	290	290	290	430	430	430	430
	305	150	150	150	150	210	210	210	310
MW168	102	460	460	460	460	690	690	690	690
	152	310	310	310	310	460	460	460	460
	305	150	150	150	150	230	230	230	310
MW181	102	500	500	500	500	750	750	750	750
	152	330	330	330	330	500	500	500	500
	305	170	170	170	170	250	250	250	310
MW194	102	530	530	530	530	800	800	800	800
	152	360	360	360	360	540	540	540	540
	305	180	180	180	180	270	270	270	310
MW200	102	550	550	550	550	830	830	830	830
	152	370	370	370	370	550	550	550	550
	305	180	180	180	180	280	280	280	310
MW290	102	800	800	800	800	1200	1200	1200	1200
	152	540	540	540	540	800	800	800	800
	305	270	270	270	270	400	400	400	400

Notes:

1. Tabulated values are based on a minimum yield strength of 385 MPa (smaller than size MW8) or 450 MPa (size MW8 and larger) and 28 MPa normal density concrete. Lengths are in millimeters.
2. Tension development lengths and tension lap splice lengths are calculated per ACI 318M-95, Sections 12.8 and 12.19, respectively.
3. For the lap splice lengths, area of steel provided was assumed to be less than twice the area of steel required (ACI 318M-95, Section 12.19.1).

TABLE 35—TENSION DEVELOPMENT AND LAP SPLICE LENGTHS FOR BARS, MULTIPLES OF BAR DIAMETER (ACI, SECTION 12.2.2)

(a) f'_c = 3000 psi [21 MPa]

Bar Sizes	Lap Class	Uncoated				Epoxy-Coated			
		Top		Other		Top		Other	
		Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2
#3-#6 [#10-#19]	A	57*d*	86*d*	44*d*	66*d*	75*d*	112*d*	66*d*	99*d*
	B	74*d*	112*d*	57*d*	86*d*	97*d*	146*d*	86*d*	129*d*
#7-#18 [#22-#57]	A	71*d*	107*d*	55*d*	82*d*	93*d*	140*d*	82*d*	124*d*
	B	93*d*	139*d*	71*d*	107*d*	122*d*	182*d*	107*d*	161*d*

(b) f'_c = 4000 psi [28 MPa]

Bar Sizes	Lap Class	Uncoated				Epoxy-Coated			
		Top		Other		Top		Other	
		Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2
#3-#6 [#10-#19]	A	50*d*	74*d*	38*d*	57*d*	65*d*	97*d*	57*d*	86*d*
	B	64*d*	97*d*	50*d*	74*d*	84*d*	126*d*	74*d*	111*d*
#7-#18 [#22-#57]	A	62*d*	93*d*	48*d*	71*d*	81*d*	121*d*	71*d*	107*d*
	B	80*d*	121*d*	62*d*	93*d*	105*d*	158*d*	93*d*	139*d*

(c) f'_c = 5000 psi [35 MPa]

Bar Sizes	Lap Class	Uncoated				Epoxy-Coated			
		Top		Other		Top		Other	
		Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2
#3-#6 [#10-#19]	A	44*d*	66*d*	34*d*	51*d*	58*d*	87*d*	51*d*	77*d*
	B	58*d*	86*d*	44*d*	66*d*	75*d*	113*d*	66*d*	100*d*
#7-#18 [#22-#57]	A	55*d*	83*d*	43*d*	64*d*	72*d*	109*d*	64*d*	96*d*
	B	72*d*	108*d*	55*d*	83*d*	94*d*	141*d*	83*d*	125*d*

Notes:

1. ACI 318/318M-95 facilitates expressing tension development lengths and tension lap splice lengths as multiples of bar diameters (*d*). Table presents these values, for various concrete strengths, for both uncoated and epoxy-coated bars. Since metric bars are soft-metric converted from inch-pound bars, table is applicable for either system of units.
2. Tabulated values are based on Grade 60 [420] reinforcing bars.
3. Tension lap splice lengths are calculated per ACI 318/318M-95, Section 12.2.2. Tabulated values for beams or columns are based on transverse reinforcement and concrete cover meeting minimum Code requirements.
4. Cases 1 and 2, which depend on the type of structural element, concrete cover, and the center-to-center spacing of the bars, are defined as:

Beams or Columns:	Case 1:	Cover at least 1.0 d_b **and** c.-c. spacing at least 2.0 d_b
	Case 2:	Cover less than 1.0 d_b **or** c.-c. spacing less than 2.0 d_b
All Others:	Case 1:	Cover at least 1.0 d_b **and** c.-c. spacing at least 3.0 d_b
	Case 2:	Cover less than 1.0 d_b **or** c.-c. spacing less than 3.0 d_b

5. Lap splice lengths are multiples of tension development lengths: Class A = 1.0 ℓ_d and Class B = 1.3 ℓ_d (ACI 318/318M-95, Section 12.15.1).
6. ACI 318/318M-95 does not allow tension lap splices of #14 or #18 [#43 or #57] bars.
7. Top bars are horizontal bars with more than 12 in. [300 mm] of concrete cast below the bars.
8. For lightweight aggregate concrete, multiply the tabulated values by 1.3.
9. For epoxy-coated bars, if the bar c.-c. spacing is at least 7.0 d_b and the concrete cover is at least 3.0 d_b, then Case 1 lengths may be multiplied by 0.918 (for top bars) or 0.8 (for other bars).

TABLE 35 (CONT.)—TENSION DEVELOPMENT AND LAP SPLICE LENGTHS FOR BARS, MULTIPLES OF BAR DIAMETER (ACI, SECTION 12.2.2)

(d) f'_c = 6000 psi [42 MPa]

Bar Sizes	Lap Class	Uncoated				Epoxy-Coated			
		Top		Other		Top		Other	
		Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2
#3-#6 [#10-#19]	A	40*d*	61*d*	31*d*	47*d*	53*d*	79*d*	47*d*	70*d*
	B	53*d*	79*d*	40*d*	61*d*	69*d*	103*d*	61*d*	91*d*
#7-#18 [#22-#57]	A	51*d*	76*d*	39*d*	58*d*	66*d*	99*d*	58*d*	87*d*
	B	66*d*	99*d*	51*d*	76*d*	86*d*	129*d*	76*d*	114*d*

(e) f'_c = 7000 psi [49 MPa]

Bar Sizes	Lap Class	Uncoated				Epoxy-Coated			
		Top		Other		Top		Other	
		Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2
#3-#6 [#10-#19]	A	37*d*	56*d*	29*d*	43*d*	49*d*	73*d*	43*d*	65*d*
	B	49*d*	73*d*	37*d*	56*d*	64*d*	95*d*	56*d*	84*d*
#7-#18 [#22-#57]	A	47*d*	70*d*	36*d*	54*d*	61*d*	92*d*	54*d*	81*d*
	B	61*d*	91*d*	47*d*	70*d*	80*d*	119*d*	70*d*	105*d*

(f) f'_c= 8000 psi [56 MPa]

Bar Sizes	Lap Class	Uncoated				Epoxy-Coated			
		Top		Other		Top		Other	
		Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2
#3-#6 [#10-#19]	A	35*d*	53*d*	27*d*	40*d*	46*d*	69*d*	40*d*	61*d*
	B	46*d*	68*d*	35*d*	53*d*	60*d*	89*d*	53*d*	79*d*
#7-#18 [#22-#57]	A	44*d*	66*d*	34*d*	51*d*	57*d*	86*d*	51*d*	76*d*
	B	57*d*	85*d*	44*d*	66*d*	74*d*	112*d*	66*d*	98*d*

Notes:

1. ACI 318/318M-95 facilitates expressing tension development lengths and tension lap splice lengths as multiples of bar diameters (*d*). Table presents these values, for various concrete strengths, for both uncoated and epoxy-coated bars. Since metric bars are soft-metric converted from inch-pound bars, table is applicable for either system of units.
2. Tabulated values are based on Grade 60 [420] reinforcing bars.
3. Tension lap splice lengths are calculated per ACI 318/318M-95, Section 12.2.2. Tabulated values for beams or columns are based on transverse reinforcement and concrete cover meeting minimum Code requirements.
4. Cases 1 and 2, which depend on the type of structural element, concrete cover, and the center-to-center spacing of the bars, are defined as:

Beams or Columns:	Case 1:	Cover at least 1.0 d_b **and** c.-c. spacing at least 2.0 d_b
	Case 2:	Cover less than 1.0 d_b **or** c.-c. spacing less than 2.0 d_b
All Others:	Case 1:	Cover at least 1.0 d_b **and** c.-c. spacing at least 3.0 d_b
	Case 2:	Cover less than 1.0 d_b **or** c.-c. spacing less than 3.0 d_b

5. Lap splice lengths are multiples of tension development lengths; Class A = 1.0 ℓ_d and Class B = 1.3 ℓ_d (ACI 318/318M-95, Section 12.15.1)
6. ACI 318/318M-95 does not allow tension lap splices of #14 or #18 [#43 or #57] bars.
7. Top bars are horizontal bars with more than 12 in. [300 mm] of concrete cast below the bars.
8. For lightweight aggregate concrete, multiply the tabulated values by 1.3.
9. For epoxy-coated bars, if the bar c.-c. spacing is at least 7.0 d_b and the concrete cover is at least 3.0 d_b, then Case 1 lengths may be multiplied by 0.918 (for top bars) or 0.8 (for other bars).

3.2 MECHANICAL SPLICES

Types of Mechanical Splices

Three basic types of mechanical splices are considered in this publication: (1) the "tension-compression" mechanical splice; (2) the "compression-only" mechanical splice which is also known as the "end-bearing" mechanical splice; and (3) the "tension-only" mechanical splice. The "tension-compression" mechanical splice can resist both tensile and compressive forces. Dowel bar mechanical splices are included in this category.

Terminology

Terminology used in this publication is defined as follows:

End-Bearing Sleeve—Device fitting over the abutting ends of two reinforcing bars for the purpose of assuring transfer of only axial compression from one bar to the other.

Coupler—Threaded device for joining reinforcing bars for the purpose of providing transfer of either axial compression or axial tension or both from one bar to the other.

Coupling Sleeve—Non-threaded device fitting over the ends of two reinforcing bars for the eventual purpose of providing transfer of either axial compression or axial tension or both from one bar to the other.

Mechanical Splice—The complete assembly of an end-bearing sleeve, a coupler, or a coupling sleeve, and possibly additional intervening material or other components to accomplish the splicing of reinforcing bars.

Bar-End Check—A check of the ends of reinforcing bars to determine whether they fit the devices intended for splicing the bars.

Tension-Compression Mechanical Splices—The ACI Building Code requirement that full mechanical splices develop in tension or compression, as required, 125 percent of the specified yield strength of the reinforcing bars usually controls design of the proprietary mechanical splice. Resistance of proprietary mechanical splices to fatigue, stress reversal, dynamic load, long-term creep, and other special conditions may vary. Test data should be secured for specific performance information for the proprietary mechanical splices considered.

Coated Reinforcing Bars

Reinforcing bars can have a coating of epoxy or zinc (galvanized) for use as a corrosion-protection system. Mechanical splices of coated reinforcing bars are made with proprietary mechanical splices in a similar way as for uncoated bars. To properly install some types of coupling sleeves on coated bars, the coating has to be completely removed from the ends of the bars over the length of the sleeve. Information on preparation of coated bars for installation of proprietary mechanical splices is presented in Tables 1 and 2.

After installation of mechanical splices on epoxy-coated reinforcing bars, the sleeves and any damaged coating on the bars adjacent to the sleeve should be touched up with compatible patching material. Typically, there will be provisions in the project specifications requiring such touch-up of the sleeves and repair of damaged coating— for example, see Section 3 in the ACI 301 Specifications.*

It should be realized that any removal or patching of coatings be done in a well-ventilated area to prevent breathing of toxic fumes.

Tension-Compression Mechanical Splices

Descriptions of proprietary tension-compression mechanical splices follow. Additional information is presented in Table 36(a) through 36(n). For a list of manufacturers, see Appendix C.

*Standard Specifications for Structural Concrete (ACI 301-96).

Cold-Swaged Coupling Sleeve

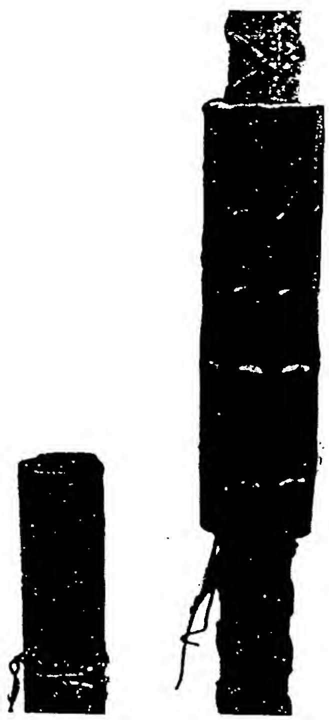


Fig. 5(a)— BarSplice

Fig. 5(b)—Richmond

The cold-swaged steel coupling sleeve uses a seamless steel tube and a portable hydraulic press with special dies. Rebars to be spliced are inserted equal distances into the tube. The press is used to deform the tube around the ends of the rebars to produce positive mechanical interlock. Bars may be shear cut, flame cut, or saw cut, however, a bar-end check is recommended. Different rebar sizes can be spliced with this system. Optional details permit use as end anchors or connections to structural steel members. Special extra long sleeves are required for splicing epoxy-coated rebars.

Table 36(a)—Tension-Compression Mechanical Splices

	Description	Cold-Swaged Coupling Sleeve			
	Manufacturer	BarSplice		Richmond	
	Figure	5(a)		5(b)	
Units		in.	mm	in.	mm
Coupling sleeve/splice	Bar size range	#3 - #18	#10 - #57	#4 - #18	#13 - #57
	Connects different bar sizes?	Yes	Yes	Yes	Yes
#18 [#57] coupling sleeve/splice installation requirements	Clear space between adjacent splices	2.63	67	2.75	70
	Minimum dowel projection	12.00	305	12.00	305
	Sleeve length	12.00	305	12.00	305
	Maximum sleeve diameter	3.75	95	3.75	95
#14 [#43] coupling sleeve/splice installation requirements	Clear space between adjacent splices	2.63	67	2.75	70
	Minimum dowel projection	9.25	235	9.25	235
	Sleeve length	8.75	222	8.75	222
	Maximum sleeve diameter	2.88	73	3.00	76
#11 [#36] coupling sleeve/splice installation requirements	Clear space between adjacent splices	1.63	41	2.00	51
	Minimum dowel projection	7.50	191	7.50	191
	Sleeve length	6.88	175	6.88	175
	Maximum sleeve diameter	2.38	60	2.50	64
#8 [#25] coupling sleeve/splice installation requirements	Clear space between adjacent splices	1.63	41	2.00	51
	Minimum dowel projection	5.75	146	5.75	146
	Sleeve length	5.00	127	5.00	127
	Maximum sleeve diameter	1.75	44	1.75	44
Bar end preparation	Cut square within 1½°?	No	No	No	No
	Special cleaning?	No	No	No	No
	Pre-drying/heating?	No	No	No	No
	Thread cutting?	No	No	No	No
	Bar-end check?	Yes	Yes	Yes	Yes
	Special coating removal (epoxy, zinc)?	No	No	No	No
Installation tools	Hand held tools adequate?	Yes (<#10) No (>#9)	Yes (<#32) No (>#29)	No	No
	Special tools required?	Yes	Yes	Yes	Yes

Cold-Swaged Threaded Coupling

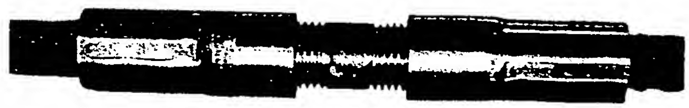


Fig. 6—BarSplice

The cold-forged threaded coupler consists of pre-threaded male and female components. The components are swaged onto the rebars using a bench press or a portable hydraulic press with special dies. No threads are required on the bar ends. Splicing of the rebars is completed by threading one pre-threaded component into the other. A three-piece position coupler is available for splicing bent or curved bars that cannot be rotated. Optional details include transition splices, connectors for structural steel members, end anchors, and flange splices with nail holes. Threads are sealed and protected for future extension applications. Special extra long sleeves are required for splicing epoxy-coated rebars.

Table 36(b)—Tension-Compression Mechanical Splices

	Description	Cold-Swaged Threaded Coupling	
	Manufacturer	BarSplice	
	Figure	6	
Units		in.	mm
Coupling sleeve/splice	Bar size range	#3 - #18	#10 - #57
	Connects different bar sizes?	Yes	Yes
#18 [#57] coupling sleeve/splice installation requirements	Clear space between adjacent splices	1.50	38
	Minimum dowel projection	0	0
	Sleeve length	14.00	356
	Maximum sleeve diameter	3.56	90
#14 [#43] coupling sleeve/splice installation requirements	Clear space between adjacent splices	1.00	25
	Minimum dowel projection	0	0
	Sleeve length	11.25	286
	Maximum sleeve diameter	2.63	67
#11 [#36] coupling sleeve/splice installation requirements	Clear space between adjacent splices	1.00	25
	Minimum dowel projection	0	0
	Sleeve length	9.75	248
	Maximum sleeve diameter	2.38	60
#8 [#25] coupling sleeve/splice installation requirements	Clear space between adjacent splices	0.75	19
	Minimum dowel projection	0	0
	Sleeve length	6.75	171
	Maximum sleeve diameter	1.75	44
Bar end preparation	Cut square within 1½°?	No	No
	Special cleaning?	No	No
	Pre-drying/heating?	No	No
	Thread cutting?	No	No
	Bar-end check?	Yes	Yes
	Special coating removal (epoxy, zinc)?	No	No
Installation tools	Hand held tools adequate?	Yes	Yes
	Special tools required?	No	No

Combination Grout-Filled/Threaded Sleeve

Fig. 7(a)—Erico

Fig. 7(b)—Richmond

This type of mechanical splice combines two common mechanical splicing techniques. One end of the sleeve is attached and secured to a rebar by means of threading. The splice is then completed when the other rebar end is inserted into the sleeve and the space between the rebar and the sleeve is filled with high-strength grout. The wide mouth opening of the sleeve allows for transitioning between different rebar sizes, as well as minor rebar misalignment.

Table 36(c)—Tension-Compression Mechanical Splices

	Description	Combination Grout-Filled/Threaded Sleeve			
	Manufacturer	Erico		Richmond	
	Figure	7(a)		7(b)	
Units		in.	mm	in.	mm
Coupling sleeve/splice	Bar size range	#6 - #18	#19 - #57	#3 - #18	#10 - #57
	Connects different bar sizes?	Yes	Yes	Yes	Yes
#18 [#57] coupling sleeve/splice installation requirements	Clear space between adjacent splices	2.25	57	2.25	57
	Minimum dowel projection	14.75	375	17.00	432
	Sleeve length	20.25	514	23.00	584
	Maximum sleeve diameter	4.50	114	4.50	114
#14 [#43] coupling sleeve/splice installation requirements	Clear space between adjacent splices	2.00	51	2.00	51
	Minimum dowel projection	11.00	279	11.00	279
	Sleeve length	15.00	381	19.50	495
	Maximum sleeve diameter	3.69	94	3.50	89
#11 [#36] coupling sleeve/splice installation requirements	Clear space between adjacent splices	1.75	44	1.50	38
	Minimum dowel projection	8.50	216	9.25	235
	Sleeve length	11.63	295	13.75	349
	Maximum sleeve diameter	3.13	79	3.00	76
#8 [#25] coupling sleeve/splice installation requirements	Clear space between adjacent splices	1.50	38	1.00	25
	Minimum dowel projection	6.00	152	6.50	165
	Sleeve length	8.63	219	11.50	292
	Maximum sleeve diameter	2.69	68	3.00	76
Bar end preparation	Cut square within 1½°?	No	No	No	No
	Special cleaning?	No	No	No	No
	Pre-drying/heating?	No	No	No	No
	Thread cutting?	Yes+	Yes+	No++	No++
	Bar-end check?	No	No	No	No
	Special coating removal (epoxy, zinc)?	No	No	No	No
Installation tools	Hand held tools adequate?	Yes	Yes	Yes	Yes
	Special tools required?	Yes (Grout Pump)	Yes (Grout Pump)	Yes (Grout Pump)	Yes (Grout Pump)

+Bar end threading normally done by Bar Fabricator.

++Bar end threaded by Splice Manufacturer.

Coupler for Thread-Deformed Rebars

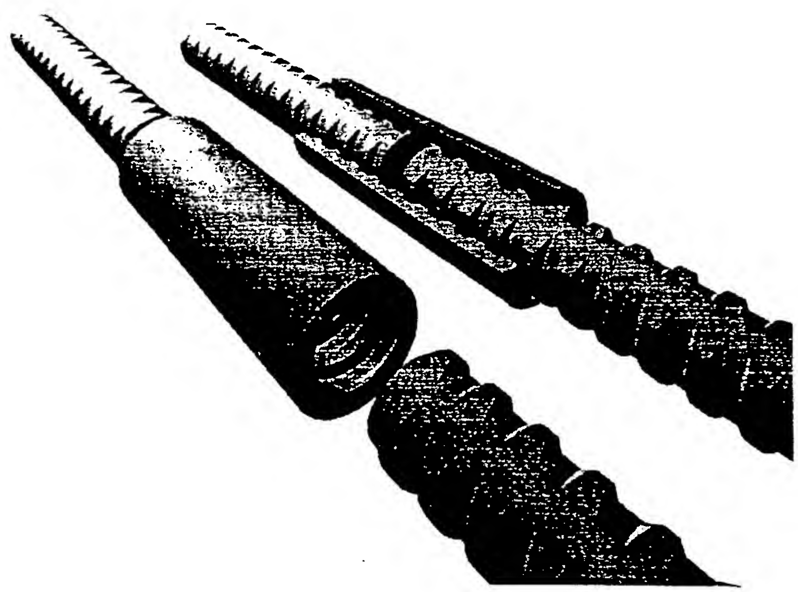


Fig. 8—DSI

This is a mechanical splice which requires special rebars with thread-like rolled deformations meeting ASTM A615 over their entire length. Splices are assembled with lock nuts and threaded couplers and the nuts are tightened to a specified torque. Alternatively, the lock nuts can be omitted when the rebars can be torqued together. Adaptations permit use for end anchorages in concrete or connection to structural steel members. Rebars may be flame or saw cut.

Table 36(d)—Tension-Compression Mechanical Splices

	Description	Coupler For Thread-Deformed Rebar*	
	Manufacturer	DSI	
	Figure	8	
Units		in.	mm
Coupling sleeve/splice	Bar size range	#6 - #18	#19 - #57
	Connects different bar sizes?	Yes	Yes
#18 [#57] coupling sleeve/splice installation requirements	Clear space between adjacent splices	3.50	89
	Minimum dowel projection	4.23	107
	Sleeve length	9.35+	237+
	Maximum sleeve diameter	3.50	89
#14 [#43] coupling sleeve/splice installation requirements	Clear space between adjacent splices	2.75	70
	Minimum dowel projection	3.55	90
	Sleeve length	7.82+	199+
	Maximum sleeve diameter	2.65	67
#11 [#36] coupling sleeve/splice installation requirements	Clear space between adjacent splices	2.25	57
	Minimum dowel projection	2.88	73
	Sleeve length	6.37+	162+
	Maximum sleeve diameter	2.25	57
#8 [#25] coupling sleeve/splice installation requirements	Clear space between adjacent splices	1.60	41
	Minimum dowel projection	1.85	47
	Sleeve length	4.03	102
	Maximum sleeve diameter	1.59	40
Bar end preparation	Cut square within 1½°?	Yes, for compression only+	
	Special cleaning?	No	No
	Pre-drying/heating?	No	No
	Thread cutting?	No	No
	Bar-end check?	No	No
	Special coating removal (epoxy, zinc)?	No	No
Installation tools	Hand held tools adequate?	Yes (<#14) No (>#11])	Yes (<#43) No (>#36)
	Special tools required?	Yes (<#14) No (>#11)	Yes (<#43) No (>#36)

*For Grade 75 [520] rebar, ultimate load capacity coupler.

+When used without lock nuts.

Coupling Sleeve With Wedge

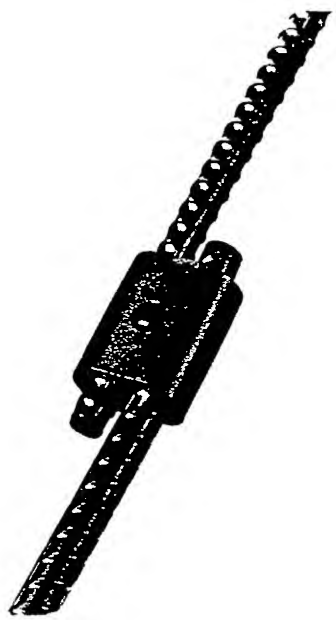


Fig. 9(a)—Erico

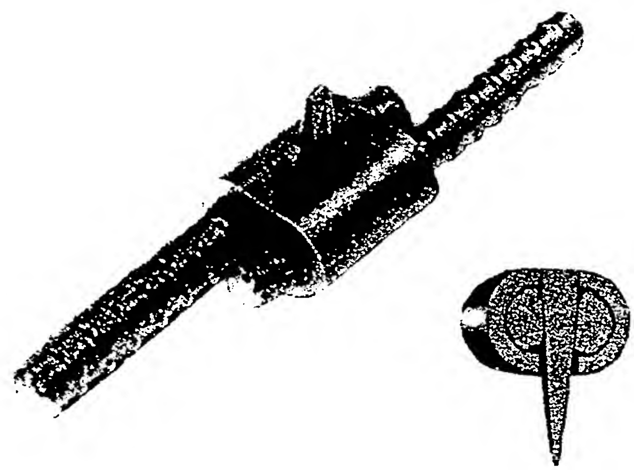


Fig. 9(b)— SSNA

Designed primarily for splicing smaller bars, sizes #3 through #6 [#10 through #19], the coupling sleeve is oval in cross-section permitting the overlapping of two rebars of the same diameter in the sleeve. Each rebar extends out of the sleeve about one bar diameter. After the sleeve is correctly positioned, a wedge-shaped round pin is driven through a hole in the flat face of the sleeve. The wedge passes between the rebars and extends through a hole opposite the hole of insertion. The wedge pin is driven with a hand-held hydraulic ram. For splicing epoxy-coated rebars, two couplings in tandem are required.

Table 36(e)—Tension-Compression Mechanical Splices

	Description	Coupling Sleeve with Wedge			
	Manufacturer	Erico		SSNA	
	Figure	9(a)		9(b)	
Units		in.	mm	in.	mm
Coupling sleeve/splice	Bar size range	#3 - #6	#10 - #19	#3 - #6	#10 - #19
	Connects different bar sizes?	Yes	Yes	No	No
#6 [#19] coupling sleeve/splice installation requirements	Clear space between adjacent splices	1.50	38	1.66	42
	Minimum dowel projection	3.00	76	4.65	118
	Sleeve length	2.75	70	3.15	80
	Maximum sleeve diameter	2.38	60	2.52	64
#5 [#16] coupling sleeve/splice installation requirements	Clear space between adjacent splices	1.69	43	1.50	38
	Minimum dowel projection	2.75	70	3.61	92
	Sleeve length	2.25	57	2.36	60
	Maximum sleeve diameter	1.94	49	1.97	50
#4 [#13] coupling sleeve/splice installation requirements	Clear space between adjacent splices	1.69	43	1.26	32
	Minimum dowel projection	2.56	65	2.58	66
	Sleeve length	1.88	48	1.58	40
	Maximum sleeve diameter	1.69	43	1.54	39
#3 [#10] coupling sleeve/splice installation requirements	Clear space between adjacent splices	1.69	43	1.26	32
	Minimum dowel projection	2.56	65	2.63	67
	Sleeve length	1.88	48	1.38	35
	Maximum sleeve diameter	1.50	38	1.18	30
Bar end preparation	Cut square within 1½°?	No	No	No	No
	Special cleaning?	No	No	No	No
	Pre-drying/heating?	No	No	No	No
	Thread cutting?	No	No	No	No
	Bar-end check?	No	No	No	No
	Special coating removal (epoxy, zinc)?	No	No	No	No
Installation tools	Hand held tools adequate?	No	No	No	No
	Special tools required?	Yes (Wedge Driver)	Yes (Wedge Driver)	Yes (Wedge Driver)	Yes (Wedge Driver)

Extruded Coupling Sleeve

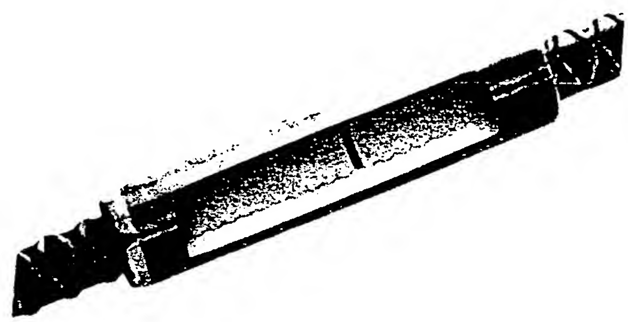


Fig. 10—DSI

This type of mechanical splice is produced by cold extruding a coupling sleeve over both rebar ends in one operation. The coupling sleeve is then centered over the butted rebar ends and is connected to one bar by tightening a setscrew. A hydraulic press, designed to fit in between closely-spaced rebars, then pushes a drawing die over the entire length of the coupling sleeve. The coupling materials flow tightly around the rebar deformations which creates a splice.

Extruded transition coupling sleeves for splicing two different size reinforcing bars are also available. Rebars may be shear cut, flame cut or saw cut, however, a bar-end check is recommended.

Table 36(f)—Tension-Compression Mechanical Splices

	Description	Extruded Coupling Sleeve	
	Manufacturer	DSI	
	Figure	10	
Units		in.	mm
Coupling sleeve/splice	Bar size range	#5 - #18	#16 - #57
	Connects different bar sizes?	Yes	Yes
#18 [#57] coupling sleeve/splice installation requirements	Clear space between adjacent splices	5.94	151
	Minimum dowel projection	20.50	521
	Sleeve length	13.44	341
	Maximum sleeve diameter	3.74	95
#14 [#43] coupling sleeve/splice installation requirements	Clear space between adjacent splices	4.50	114
	Minimum dowel projection	17.31	440
	Sleeve length	9.44	240
	Maximum sleeve diameter	2.83	72
#11 [#36] coupling sleeve/splice installation requirements	Clear space between adjacent splices	4.50	114
	Minimum dowel projection	17.31	440
	Sleeve length	7.81	198
	Maximum sleeve diameter	2.56	65
#8 [#25] coupling sleeve/splice installation requirements	Clear space between adjacent splices	3.19	81
	Minimum dowel projection	10.25	260
	Sleeve length	5.56	141
	Maximum sleeve diameter	1.77	45
Bar end preparation	Cut square within 1½°?	No	No
	Special cleaning?	No	No
	Pre-drying/heating?	No	No
	Thread cutting?	No	No
	Bar-end check?	Yes	Yes
	Special coating removal (epoxy, zinc)?	No	No
Installation tools	Hand held tools adequate?	No	No
	Special tools required?	Yes	Yes

Grout-Filled Coupling Sleeve

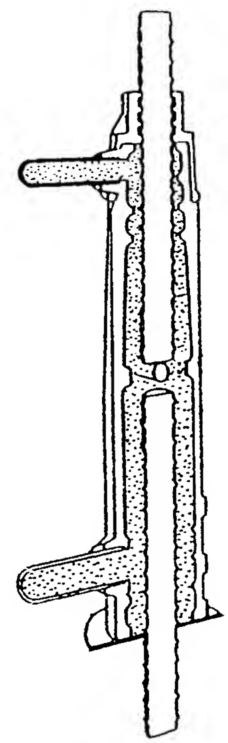


Fig. 11—SSNA

The double-frustrum-shaped coupling sleeve is filled with a cement-based, nonshrink, high-early strength grout. Rebars to be spliced are inserted into the sleeve to meet at the center of the sleeve. The space between rebar and sleeve is filled with nonshrink grout to transfer stress between the external deformations on the rebar and internal deformations in the sleeve. No special end preparation of the rebars is required. The relatively wide sleeves also can accommodate minor rebar misalignments, and combinations of different size rebars.

Table 36(g)—Tension-Compression Mechanical Splices

	Description	Grout-Filled Coupling Sleeve	
	Manufacturer	SSNA	
	Figure	11	
Units		in.	mm
Coupling sleeve/splice	Bar size range	#3 - #18	#10 - #57
	Connects different bar sizes?	Yes	Yes
#18 [#57] coupling sleeve/splice installation requirements	Clear space between adjacent splices	1.00	25
	Minimum dowel projection	17.00	432
	Sleeve length	36.22	920
	Maximum sleeve diameter	4.72	120
#14 [#43] coupling sleeve/splice installation requirements	Clear space between adjacent splices	1.00	25
	Minimum dowel projection	11.42	290
	Sleeve length	24.41	620
	Maximum sleeve diameter	3.46	88
#11 [#36] coupling sleeve/splice installation requirements	Clear space between adjacent splices	1.00	25
	Minimum dowel projection	8.98	228
	Sleeve length	19.49	495
	Maximum sleeve diameter	3.03	77
#8 [#25] coupling sleeve/splice installation requirements	Clear space between adjacent splices	1.00	25
	Minimum dowel projection	6.50	165
	Sleeve length	14.57	370
	Maximum sleeve diameter	2.48	63
Bar end preparation	Cut square within 1½°?	No	No
	Special cleaning?	No	No
	Pre-drying/heating?	No	No
	Thread cutting?	No	No
	Bar-end check?	No	No
	Special coating removal (epoxy, zinc)?	No	No
Installation tools	Hand held tools adequate?	Yes	Yes
	Special tools required?	Yes (Grout Pump)	Yes (Grout Pump)

Hot-Forged Coupling Sleeve

Fig. 12—Harris

This is a mechanical splice which uses a specially machined sleeve. The sleeve is heated to a malleable temperature and fitted over the end of one rebar. The second rebar end is inserted into the hot sleeve. A portable hydraulic forge forces the sleeve's inner wall onto and around the deformations on the rebars. Contraction of the sleeve upon cooling causes additional bond which provides increased tensile strength to the splice. Rebars may be shear cut, flame cut, or saw cut, however, a bar-end check is recommended.

Table 36(h)—Tension-Compression Mechanical Splices

	Description	Hot-Forged Coupling Sleeve	
	Manufacturer	Harris	
	Figure	12	
Units		in.	mm
Coupling sleeve/splice	Bar size range	#5 - #18	#16 - #57
	Connects different bar sizes?	Yes	Yes
#18 [#57] coupling sleeve/splice installation requirements	Clear space between adjacent splices	3.38	86
	Minimum dowel projection	Vert.: 18.00 Horz.: 20.00	Vert.: 457 Horz.: 508
	Sleeve length	9.00	229
	Maximum sleeve diameter	3.25	83
#14 [#43] coupling sleeve/splice installation requirements	Clear space between adjacent splices	2.50	64
	Minimum dowel projection	Vert.: 18.00 Horz.: 20.00	Vert.: 457 Horz.: 508
	Sleeve length	7.00	178
	Maximum sleeve diameter	2.75	70
#11 [#36] coupling sleeve/splice installation requirements	Clear space between adjacent splices	2.13	54
	Minimum dowel projection	Vert.: 13.00 Horz.: 15.00	Vert.: 330 Horz.: 381
	Sleeve length	5.50	140
	Maximum sleeve diameter	2.25	572
#8 [#25] coupling sleeve/splice installation requirements	Clear space between adjacent splices	1.50	38
	Minimum dowel projection	Vert.: 13.00 Horz.: 15.00	Vert.: 330 Horz.: 381
	Sleeve length	5.50	140
	Maximum sleeve diameter	1.75	44
Bar end preparation	Cut square within 1½°?	No	No
	Special cleaning?	Remove loose particles.	
	Pre-drying/heating?	Yes (Coupler)	Yes (Coupler)
	Thread cutting?	No	No
	Bar-end check?	Yes	Yes
	Special coating removal (epoxy, zinc)?	No	No
Installation tools	Hand held tools adequate?	No	No
	Special tools required?	Yes	Yes

Shear Bolt Coupling Sleeve

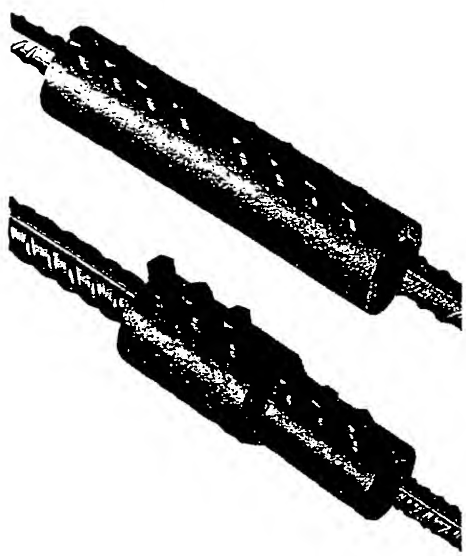


Fig. 13(a)—Bar-Lock

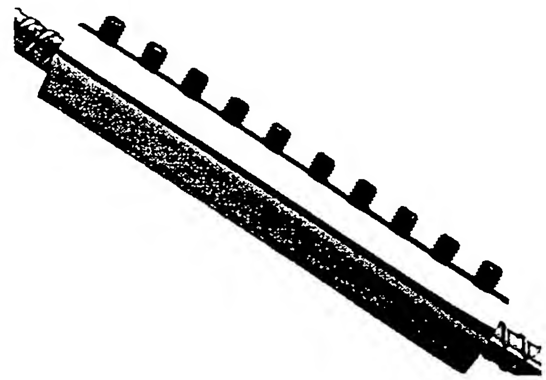


Fig. 13(b)—BarSplice

This type of mechanical splice consists of a sleeve with shear head bolts. The rebars are inserted to meet at a stop at the center of the sleeve and the bolts are tightened. The tightening process embeds the cone-pointed bolts into the rebars, which also forces the rebars into contact with internal gripping rails or with the sleeve interior wall. The heads of the bolts shear off at a prescribed tightening torque. The bolts can be tightened using a standard wrench or pneumatic nut driver. For making a splice between two fixed rebars, sleeves without a center stop are available, which can be slipped onto one rebar and subsequently repositioned over the two rebar ends.

Table 36(i)—Tension-Compression Mechanical Splices

	Description	Shear Bolt Coupling Sleeve			
	Manufacturer	Bar-Lock		BarSplice	
	Figure	13(a)		13(b)	
Units		in.	mm	in.	mm
Coupling sleeve/splice	Bar size range	#3 - #18	#10 - #57	#3 - #14	#10 - #43
	Connects different bar sizes?	Yes	Yes	Yes	Yes
#18 [#57] coupling sleeve/splice installation requirements	Clear space between adjacent splices	0	0	N/A	N/A
	Minimum dowel projection	13.50	343	N/A	N/A
	Sleeve length	27.90	709	N/A	N/A
	Maximum sleeve diameter	4.30	109	N/A	N/A
#14 [#43] coupling sleeve/splice installation requirements	Clear space between adjacent splices	0	0	1.50	38
	Minimum dowel projection	8.00	203	10.75	273
	Sleeve length	16.50	419	21.50	546
	Maximum sleeve diameter	3.50	89	3.44	87
#11 [#36] coupling sleeve/splice installation requirements	Clear space between adjacent splices	0	0	1.38	35
	Minimum dowel projection	5.50	140	10.75	273
	Sleeve length	11.50	292	21.50	546
	Maximum sleeve diameter	3.10	79	2.94	75
#8 [#25] coupling sleeve/splice installation requirements	Clear space between adjacent splices	0	0	0.88	22
	Minimum dowel projection	3.80	97	7.63	194
	Sleeve length	8.00	203	15.25	387
	Maximum sleeve diameter	2.20	56	2.19	56
Bar end preparation	Cut square within 1½°?	No	No	No	No
	Special cleaning?	No	No	No	No
	Pre-drying/heating?	No	No	No	No
	Thread cutting?	No	No	No	No
	Bar-end check?	No	No	Yes	Yes
	Special coating removal (epoxy, zinc)?	No	No	No	No
Installation tools	Hand held tools adequate?	Yes	Yes	Yes	Yes
	Special tools required?	No	No	No	No

Steel-Filled Coupling Sleeve

Fig. 14—Erico

Three types are available:

a) compression (only)

b) 125% f_y tension-compression

c) minimum ultimate tensile strength of the rebar

The steel-filled coupling sleeve is a mechanical splice in which molten metal or "steel filler" interlocks the grooves inside the sleeve with the deformations on the rebar. Special details permit use as end anchors or connections to structural steel members.

Shear cut, flame cut, or saw cut ends can be used as the "steel filler" fills the space between the ends of the rebars, however, a bar-end check is recommended.

Table 36(j)—Tension-Compression Mechanical Splices

	Description	Steel-Filled Coupling Sleeve	
	Manufacturer	Erico	
	Figure	14	
Units		in.	mm
Coupling sleeve/splice	Bar size range	#4 - #18	#13 - #57
	Connects different bar sizes?	Yes	Yes
#18 [#57] coupling sleeve/splice installation requirements	Clear space between adjacent splices	3.75	95
	Minimum dowel projection	4.88	124
	Sleeve length	9.00	229
	Maximum sleeve diameter	3.75	95
#14 [#43] coupling sleeve/splice installation requirements	Clear space between adjacent splices	3.00	76
	Minimum dowel projection	3.88	98
	Sleeve length	7.00	178
	Maximum sleeve diameter	3.00	76
#11 [#36] coupling sleeve/splice installation requirements	Clear space between adjacent splices	2.50	64
	Minimum dowel projection	3.38	86
	Sleeve length	6.00	152
	Maximum sleeve diameter	2.50	64
#8 [#25] coupling sleeve/splice installation requirements	Clear space between adjacent splices	2.25	57
	Minimum dowel projection	2.88	73
	Sleeve length	5.00	127
	Maximum sleeve diameter	1.88	48
Bar end preparation	Cut square within 1½°?	No	No
	Special cleaning?	Remove concrete and loose rust.	
	Pre-drying/heating?	Yes	Yes
	Thread cutting?	No	No
	Bar-end check?	Yes	Yes
	Special coating removal (epoxy, zinc)?	Yes	Yes
Installation tools	Hand held tools adequate?	No	No
	Special tools required?	Yes	Yes

Straight Thread Coupler with Upset Rebar Ends

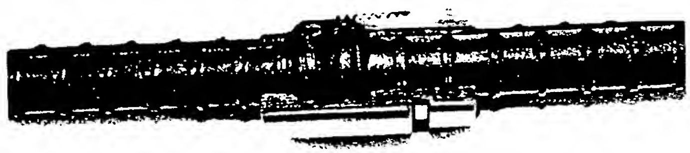
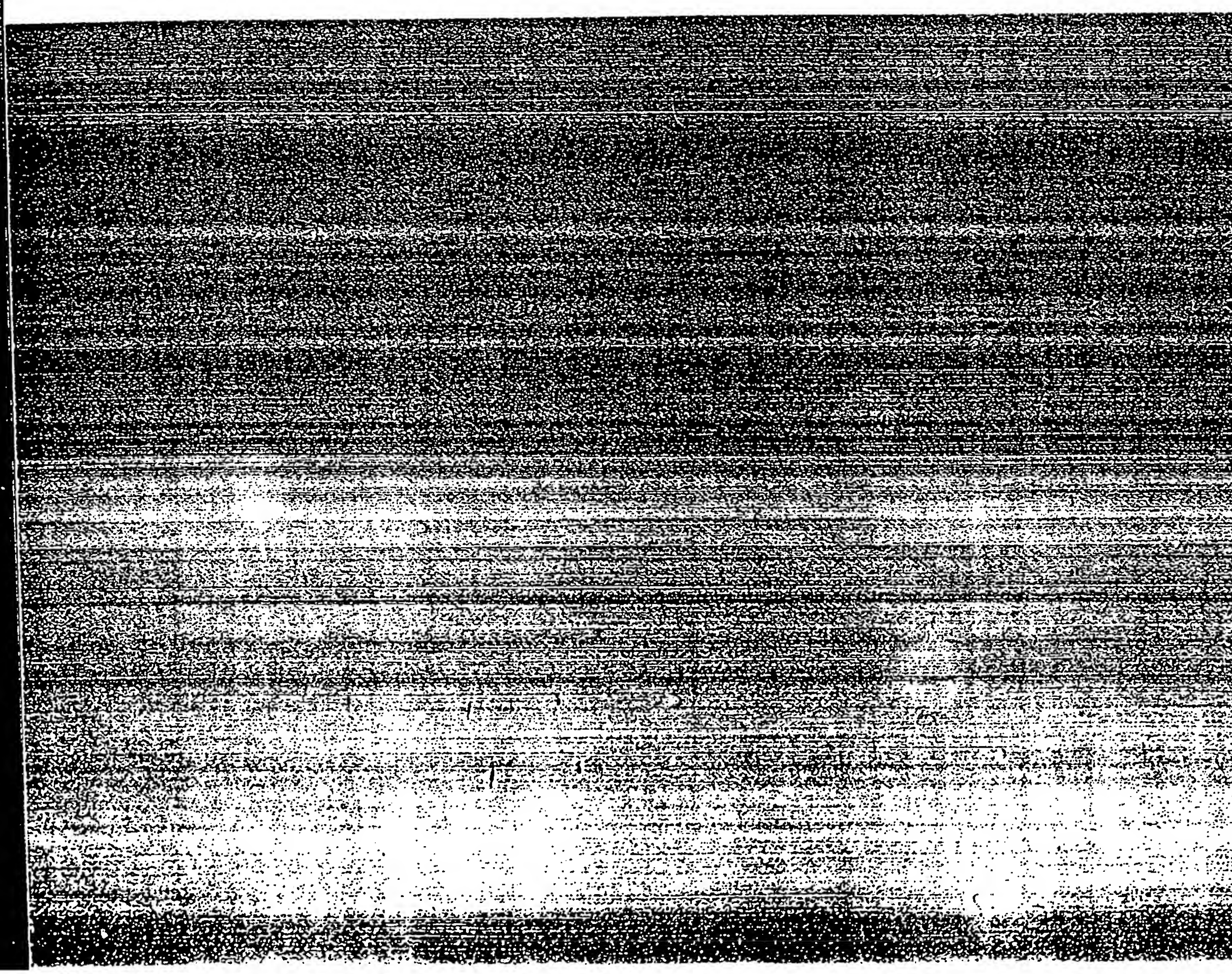


Fig. 15—HRC

This is a mechanical splice consisting of forming heads on the ends of the rebars to be connected using a hydraulic machine from the splice manufacturer, which is designed to fit between closely-spaced rebars. The upset rebar ends are butted up to each other and are held in place using a male and female straight threaded coupler that is positioned onto the rebars prior to forming the heads. The coupler is installed by turning either the male or female component and tightening to the manufacturer's recommended torque; no rotation of the rebar is required. Bent or curved rebars can be spliced with the same device. Adaptations permit use for end anchorages in concrete or connection to threaded rod. Rebar ends may be sheared, flame cut or saw cut.

CRSI

FOUNDED 1924



REINFORCEMENT ANCHORAGES AND SPLICES

ERRATA FOR FOURTH EDITION, 1997

(FEBRUARY 1998)

CRSI
FOUNDED 1924
CONCRETE REINFORCING STEEL INSTITUTE

ASTM STANDARD METRIC REINFORCING BARS

BAR SIZE DESIGNATION	NOMINAL DIMENSIONS		
	AREA (mm^2)	MASS (kg/m)	DIAMETER (mm)
#10	71	0.560	9.5
#13	129	0.994	12.7
#16	199	1.552	15.9
#19	284	2.235	19.1
#22	387	3.042	22.2
#25	510	3.973	25.4
#29	645	5.060	28.7
#32	819	6.404	32.3
#36	1006	7.907	35.8
#43	1452	11.38	43.0
#57	2581	20.24	57.3

The current A615M specification covers bar sizes #43 and #57 in Grade 420, and bar sizes #36, #43, and #57 in Grade 520. The current A706 specification also covers bar sizes #43 and #57. Bar sizes #43 and #57 are not included in the A616M and A617M specifications.

Page 18, Table 10—Title of table is in error; Table 10 is for epoxy-coated bars, rather than uncoated bars.

Page 45—First paragraph in right column, last sentence; the reference at the end of the sentence should be to Tables 36(a) through 36(n) and 37, not 1 and 2.

Page 54—Last sentence should be removed. Either line-out the last sentence or use enclosed sticker to completely replace paragraph.

Page 62, Fig. 13(b)—Photo shown is not representative of BarSplice's device. Replace with following:

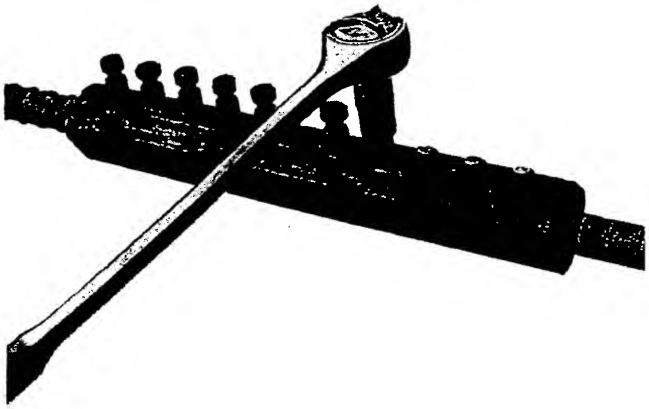


Fig. 13(b)—BarSplice

Page 69, Table 36(l)—Fox-Howlett device, #8 coupling; the maximum sleeve diameter is 1.31 in., not 131 in.

Page 72—Illustration for Meadow Steel Products device was inadvertently excluded. Add following figure:

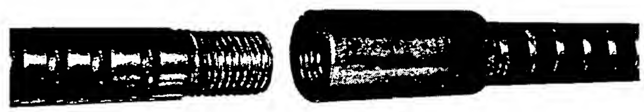


Fig. 18(d)—Meadow

Page 73, Table 36(n)—Column of data for Meadow Steel Products device was inadvertently excluded. Replace entire table with the table on the next page.

Page 82, Fig. 24—Bar call-out at 1st floor level, right-most bar stack; the bar call-out should be 2 bars, not 4 bars.

Page 99, Tables 7(a) through 7(f).—Titles of tables are in error; these tables are for epoxy-coated bars, rather than uncoated bars.

Page 100—Information on Meadow Steel Products was inadvertently excluded. Replace the entire page i.e. Appendix C, with the Appendix C on page 4 herein.

Table 36(n)—Tension-Compression Mechanical Splices

	Description	Non-Upset Straight Thread Coupler							
	Manufacturer	BarSplice		Dayton		Richmond		Meadow	
	Figure	18(a)		18(b)		18(c)		18(d)	
Units		in.	mm	in.	mm	in.	mm	in.	mm
Coupling sleeve/splice	Bar size range	#3 - #11	#10 - #36	#4 - #11	#13 - #36	#8 - #18	#25 - #57	#4 - #11	#13 - #36
	Connects different bar sizes?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
#18 [#57] coupling sleeve/splice installation requirements	Clear space between adjacent splices	N/A	N/A	N/A	N/A	1.50	38	N/A	N/A
	Minimum dowel projection	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Sleeve length	N/A	N/A	N/A	N/A	5.50	140	N/A	N/A
	Maximum sleeve diameter	N/A	N/A	N/A	N/A	3.63	92	N/A	N/A
#14 [#43] coupling sleeve/splice installation requirements	Clear space between adjacent splices	N/A	N/A	N/A	N/A	1.00	25	N/A	N/A
	Minimum dowel projection	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Sleeve length	N/A	N/A	N/A	N/A	4.25	108	N/A	N/A
	Maximum sleeve diameter	N/A	N/A	N/A	N/A	2.75	70	N/A	N/A
#11 [#36] coupling sleeve/splice installation requirements	Clear space between adjacent splices	1.00	25	0+++	0+++	1.00	25	1.00	25
	Minimum dowel projection	0	0	0	0	N/A	N/A	0	0
	Sleeve length	4.50	114	4.38	111	3.63	92	4.50	114
	Maximum sleeve diameter	2.00	51	1.94	49	2.25	57	2.00	51
#8 [#25] coupling sleeve/splice installation requirements	Clear space between adjacent splices	0.75	19	0+++	0+++	1.00	25	0.75	19
	Minimum dowel projection	0	0	0	0	N/A	N/A	0	0
	Sleeve length	3.00	76	3.13	79	2.75	70	3.00	76
	Maximum sleeve diameter	1.50	38	1.38	35	1.63	41	1.50	38
Bar end preparation	Cut square within 1 1/2°?	No	No	No	No	No	No	No	No
	Special cleaning?	No	No	No	No	No	No	No	No
	Pre-drying/heating?	No	No	No	No	No++	No++	No	No
	Thread cutting?	Yes	Yes	Yes+	Yes+	No	No	Yes	Yes
	Bar-end check?	No	No	No	No	No	No	No	No
	Special coating removal (epoxy, zinc)?	No	No	No	No	No	No	No	No
Installation tools	Hand held tools adequate?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Special tools required?	No	No	No	No	No*	No*	No	No

+Bar end threading normally done by Bar Fabricator.
++Bar end threaded by Splice Manufacturer.
+++Flange removed.
*Friction weld made by Splice Manufacturer.

Bar-Lock Coupler Systems (Bar-Lock)
P. O. Box 28280
Bellingham, WA 98228
Tel: 360-738-1891
Fax: 360-738-1887

BarSplice Products, Inc. (BarSplice)
1300 Granger Hall Road
Beavercreek, OH 45430
Tel: 937-427-6466
Fax: 937-427-6470

Dayton Superior Corporation (Dayton)
721 Richard Street
Miamisburg, OH 45342
Tel: 937-866-0711
Fax: 937-866-9448

Dywidag Systems International, USA, Inc. (DSI)
107 Beaver Brook Road
Lincoln Park, NJ 07035
Tel: 201-628-8700
Fax: 201-628-8253

Erico, Inc. (Erico)
34600 Solon Road
Cleveland, OH 44139
Tel: 216-248-0100
Fax: 216-349-3163

Fox-Howlett Industries, Inc. (Fox-Howlett)
744 Folger Avenue
Berkeley, CA 94710
Tel: 510-841-1016
Fax: 510-841-1018

Harris Rebar, Inc. (Harris)
P. O. Box 9990
Stoney Creek, Ontario, CANADA L8G 3Y4
Tel: 905-662-5700
Fax: 905-561-7326

Headed Reinforcement Corp. (HRC)
11200 Condor Avenue
Fountain Valley, CA 92708
Tel: 714-557-1455
Fax: 714-557-4460

Meadow Steel Products, Co. (Meadow)
5110 Santa Fe Road
Tampa, FL 33619
Tel: 813-248-1944
Fax: 813-248-0703

Richmond Screw Anchor Co., Inc. (Richmond)
7214 Burns Street
Richland Hills
Ft. Worth, TX 76118
Tel: 817-284-4981
Fax: 817-284-4504

Splice Sleeve North America (SSNA)
24770 Lyonia Lane
Bonita Springs, FL 34134
Tel: 941-948-1771
Fax: 941-948-1770

Mechanical Splice	Splice Manufacturer										
	Bar-Lock	BarSplice	Dayton	DSI	Erico	Fox-Howlett	Harris	HRC	Meadow	Richmond	SSNA
Tension-Compression Mechanical Splice											
Cold-Swaged Coupling Sleeve		X								X	
Cold-Swaged Threaded Coupling		X									
Combination Grout-Filled/Threaded Sleeve					X					X	
Coupler for Thread-Deformed Rebar				X							
Coupling Sleeve with Wedge					X						X
Extruded Coupling Sleeve				X							
Grout-Filled Coupling Sleeve											X
Hot-Forged Coupling Sleeve							X				
Shear Bolt Coupling Sleeve	X	X									
Steel-Filled Coupling Sleeve					X						
Straight Thread Coupler with Upset Rebar Ends								X			
Taper-Threaded Coupler					X	X		X			
Upset Straight Thread Coupler			X					X		X	
Non-Upset Straight Thread Coupler		X	X						X	X	
Compression-Only Mechanical Splice											
Bolted Strap Coupling Sleeve					X		X				
Steel-Filled Coupling Sleeve					X						
Wedge-Locking Coupling Sleeve		X									

Table 36(k)—Tension-Compression Mechanical Splices

	Description	Straight Thread Coupler with Upset Rebar Ends	
	Manufacturer	HRC	
	Figure	15	
Units		in.	mm
Coupling sleeve/splice	Bar size range	#4 - #14	#13 - #43
	Connects different bar sizes?	Yes	Yes
#18 [#57] coupling sleeve/splice installation requirements	Clear space between adjacent splices	N/A	N/A
	Minimum dowel projection	N/A	N/A
	Sleeve length	N/A	N/A
	Maximum sleeve diameter	N/A	N/A
#14 [#43] coupling sleeve/splice installation requirements	Clear space between adjacent splices	1.25	32
	Minimum dowel projection	1.75	44
	Sleeve length	4.50	114
	Maximum sleeve diameter	3.50	89
#11 [#36] coupling sleeve/splice installation requirements	Clear space between adjacent splices	1.25	32
	Minimum dowel projection	1.50	38
	Sleeve length	4.00	102
	Maximum sleeve diameter	2.88	73
#8 [#25] coupling sleeve/splice installation requirements	Clear space between adjacent splices	1.25	32
	Minimum dowel projection	1.19	30
	Sleeve length	3.00	76
	Maximum sleeve diameter	2.13	54
Bar end preparation	Cut square within 1½°?	No	No
	Special cleaning?	No	No
	Pre-drying/heating?	Yes*	Yes*
	Thread cutting?	No	No
	Bar-end check?	No	No
	Special coating removal (epoxy, zinc)?	No	No
Installation tools	Hand held tools adequate?	Yes	Yes
	Special tools required?	No	No

*Heating used in bar upsetting. Bar upsetting done by Bar Fabricator or Splice Manufacturer.

Taper-Threaded Coupler

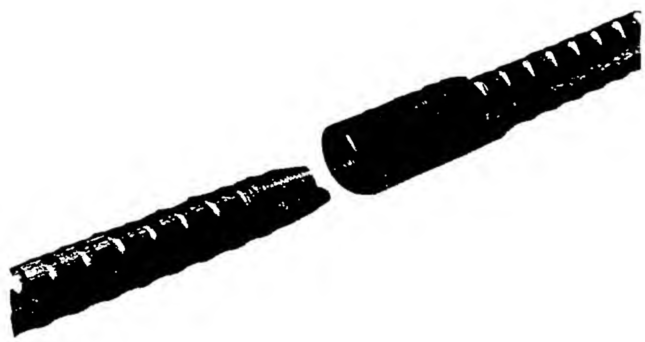


Fig. 16(a)—Erico

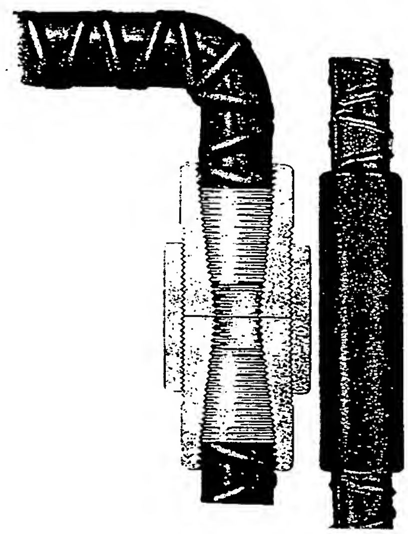


Fig. 16(b)—Fox-Howlett

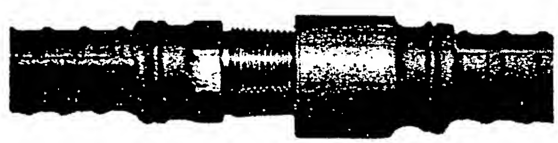


Fig. 16(c)—HRC

This is a mechanical splice consisting of a taper threaded coupler that joins rebars with matching taper threads. The coupler is installed by turning the rebar or sleeve with wrenches to the manufacturer's specified torque. For splicing bent or curved rebars, special position couplers with collars are used. Adaptations permit use for end anchorages in concrete or connection to structural steel members. Rebar ends may be shear cut or saw cut. Rebar ends require taper threading over a specified length.

Table 36(I)—Tension-Compression Mechanical Splices

	Description	Taper-Threaded Coupler					
	Manufacturer	Erico		Fox-Howlett		HRC	
	Figure	16(a)		16(b)		16(c)	
Units		in.	mm	in.	mm	in.	mm
Coupling sleeve/splice	Bar size range	#4 - #18	#13 - #57	#6 - #18	#19 - #57	#5 - #18	#16 - #57
	Connects different bar sizes?	Yes	Yes	Yes	Yes	Yes	Yes
#18 [#57] coupling sleeve/splice installation requirements	Clear space between adjacent splices	0.38	10	1.25	32	1.25	32
	Minimum dowel projection	N/A	N/A	3.50	89	3.50	89
	Sleeve length	6.50	165	6.25	159	7.50	191
	Maximum sleeve diameter	3.00	76	3.00	76	3.38	86
#14 [#43] coupling sleeve/splice installation requirements	Clear space between adjacent splices	0.25	6	1.25	32	1.25	32
	Minimum dowel projection	N/A	N/A	2.50	64	3.13	79
	Sleeve length	5.25	133	4.50	114	6.25	159
	Maximum sleeve diameter	2.25	57	2.25	57	2.75	70
#11 [#36] coupling sleeve/splice installation requirements	Clear space between adjacent splices	0.25	6	1.25	32	1.25	32
	Minimum dowel projection	N/A	N/A	2.50	64	2.38	60
	Sleeve length	4.25	108	4.25	108	5.00	127
	Maximum sleeve diameter	1.88	48	1.88	48	2.38	60
#8 [#25] coupling sleeve/splice installation requirements	Clear space between adjacent splices	0.19	5	1.25	32	1.25	32
	Minimum dowel projection	N/A	N/A	2.00	51	1.75	44
	Sleeve length	3.34	85	3.00	76	4.00	102
	Maximum sleeve diameter	1.38	35	131	33	1.50	38
Bar end preparation	Cut square within 1½°?	No	No	No	No	No	No
	Special cleaning?	No	No	No	No	No	No
	Pre-drying/heating?	No	No	No	No	No	No
	Thread cutting?	Yes+	Yes+	Yes+	Yes+	No	No
	Bar-end check?	No	No	No	No	No	No
	Special coating removal (epoxy, zinc)?	No	No	No	No	No	No
Installation tools	Hand held tools adequate?	Yes	Yes	Yes	Yes	Yes	Yes
	Special tools required?	No	No	No	No	No*	No*

+Bar end threading normally done by Bar Fabricator.
*Friction weld made by Splice Manufacturer.

Upset Straight Thread Coupler

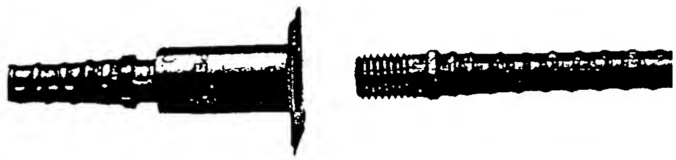


Fig. 17(a)—Dayton

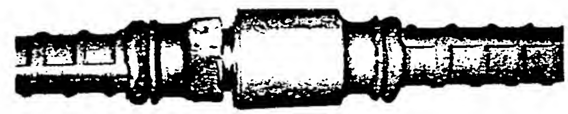


Fig. 17(b)—HRC

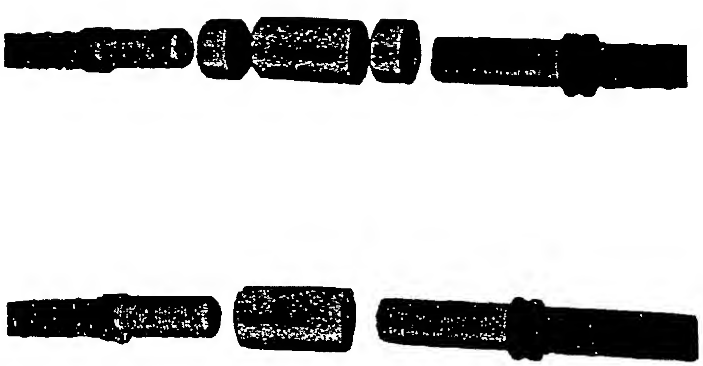


Fig. 17(c)—Richmond

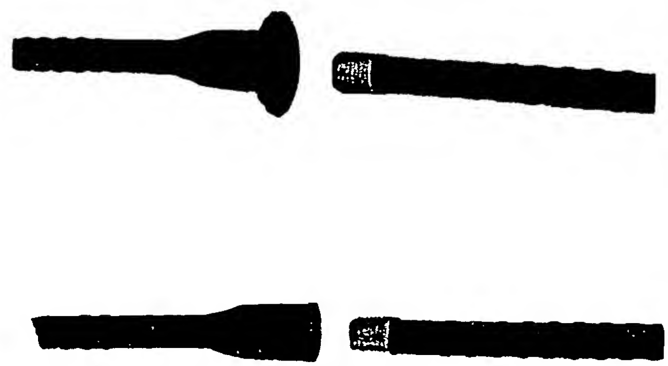


Fig. 17(d)—Richmond

This is a mechanical splice consisting of a coupler with internal parallel NC (National Course) or UN (Unified National) threads that join two rebars that have been "upset" or built-up and threaded with matching external parallel threads. The "upsetting" or building up of the rebar ends permits the net cross-sectional area of the threaded end of the rebar to have the same cross-sectional area as the original rebar.

This type of splice can either be in three pieces (the two rebar ends and internally-threaded coupler) or in two pieces with the coupler integrally forged or pre-assembled onto the rebar end. These systems are available with additional couplers such as weld-on couplers, transitional couplers, positional couplers, and mechanical anchors.

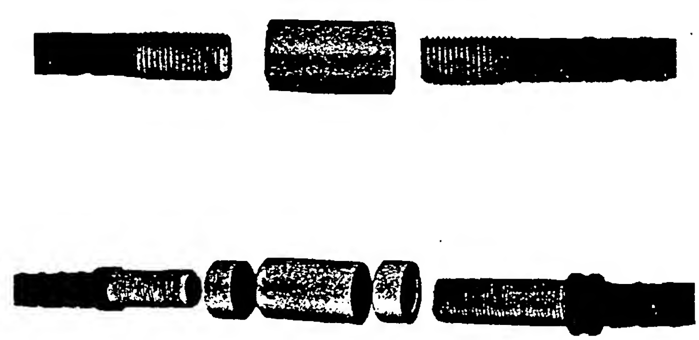


Fig. 17(e)—Richmond

Table 36(m)—Tension-Compression Mechanical Splices

	Description	Upset Straight Thread Coupler									
	Manufacturer	Dayton		HRC		Richmond					
	Figure	17(a)		17(b)		17(c)		17(d)		17(e)	
Units		in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
Coupling sleeve/splice	Bar size range	#4 - #11	#13 - #36	#5 - #18	#16 - #57	#8 - #18	#25 - #57	#4 - #11	#13 - #36	#4 - #11	#13 -
	Connects different bar sizes?	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes
#18 [#57] coupling sleeve/splice installation requirements	Clear space between adjacent splices	N/A	N/A	1.25	32	1.50	38	N/A	N/A	N/A	N/A
	Minimum dowel projection	N/A	N/A	3.50	89	N/A	N/A	N/A	N/A	N/A	N/A
	Sleeve length	N/A	N/A	7.50	191	5.50	140	N/A	N/A	N/A	N/A
	Maximum sleeve diameter	N/A	N/A	3.38	86	3.63	92	N/A	N/A	N/A	N/A
#14 [#43] coupling sleeve/splice installation requirements	Clear space between adjacent splices	N/A	N/A	1.25	32	1.00	25	N/A	N/A	N/A	N/A
	Minimum dowel projection	N/A	N/A	3.13	79	N/A	N/A	N/A	N/A	N/A	N/A
	Sleeve length	N/A	N/A	6.25	159	4.25	108	N/A	N/A	N/A	N/A
	Maximum sleeve diameter	N/A	N/A	2.75	70	2.75	67	N/A	N/A	N/A	N/A
#11 [#36] coupling sleeve/splice installation requirements	Clear space between adjacent splices	0^{++}	0^{++}	1.25	32	1.00	25	1.00	25	1.00	2
	Minimum dowel projection	0	0	2.38	60	N/A	N/A	N/A	N/A	N/A	N/
	Sleeve length	4.00	102	5.00	127	3.63	92	3.75	95	3.63	9
	Maximum sleeve diameter	2.31	59	2.38	60	2.25	57	2.19^{++}	56^{++}	2.25	5
#8 [#25] coupling sleeve/splice installation requirements	Clear space between adjacent splices	0^{++}	0^{++}	1.25	32	1.00	25	1.00	25	1.00	2
	Minimum dowel projection	0	0	1.75	44	N/A	N/A	N/A	N/A	N/A	N/
	Sleeve length	2.88	73	4.00	102	2.75	70	3.13	79	2.75	7
	Maximum sleeve diameter	1.69	43	1.50	38	1.63	41	1.63^{++}	41^{++}	1.63	4
Bar end preparation	Cut square within 1½°?	No	No	No	No	No	No	No	No	No	N
	Special cleaning?	No	No	No	No	No	No	No	No	No	N
	Pre-drying/heating?	No	No	No	No	No	No	No	No	No	N
	Thread cutting?	Yes	Yes	No	No	No^{+}	No^{+}	No^{+}	No^{+}	Yes	Y
	Bar-end check?	No	No	No	No	No	No	No	No	No	N
	Special coating removal (epoxy, zinc)?	No	No	No	No	No	No	No	No	No	N
Installation tools	Hand held tools adequate?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Y
	Special tools required?	No	No	No*	No*	No*	No*	No	No	No	N

+ Threaded by Splice Manufacturer.

++ Flange removed.

*Friction weld made by Splice Manufacturer.

Non-Upset Straight Thread Coupler

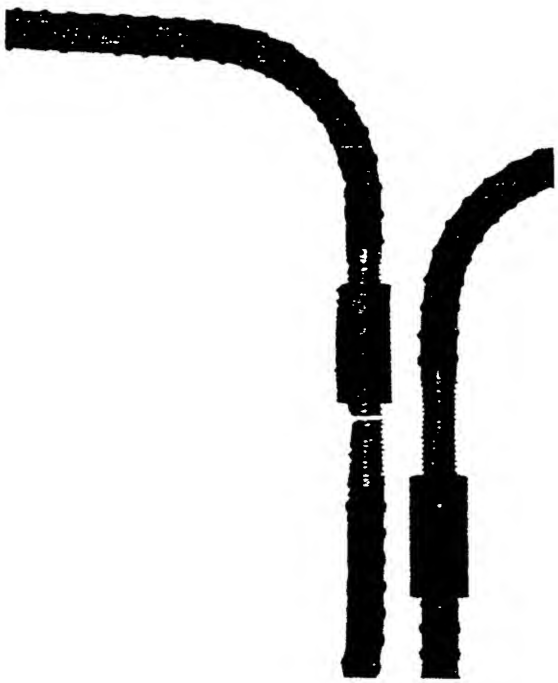


Fig. 18(a)—BarSplice

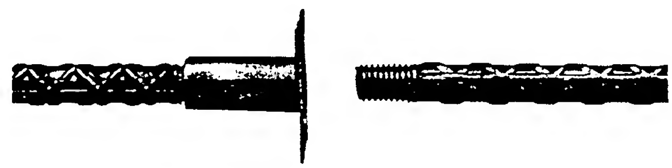


Fig. 18(b)—Dayton

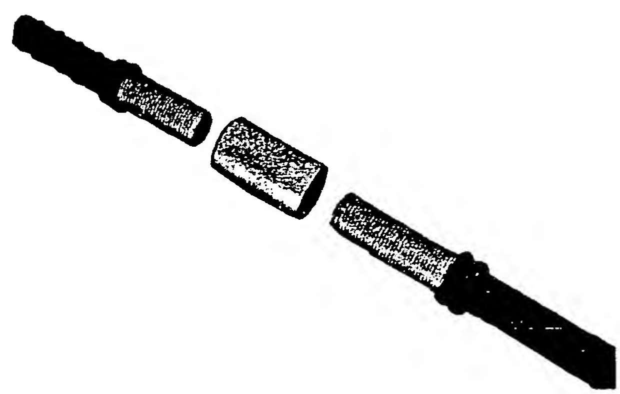


Fig. 18(c)—Richmond

This is a mechanical splice consisting of a coupler with internal parallel NC (National Coarse) or UN (Unified National) threads that joins two rebars with matching external parallel threads.

Since the cutting of threads reduces the net cross-sectional area of the rebar, some manufacturers use rebars one size larger while other manufacturers use rebar with tensile and yield strengths sufficient to overcome the loss of net area.

This type of splice can either be in three pieces (the two bar ends and the internally-threaded coupler) or in two pieces with the coupler integrally forged onto one rebar end. These systems are available with additional couplers such as weld-on couplers, transition couplers, and mechanical anchors.

Table 36(n)—Tension-Compression Mechanical Splices

	Description	Non-Upset Straight Thread Coupler					
	Manufacturer	BarSplice		Dayton		Richmond	
	Figure	18(a)		18(b)		18(c)	
Units		in.	mm	in.	mm	in.	mm
Coupling sleeve/splice	Bar size range	#3 - #11	#10 - #36	#4 - #11	#13 - #36	#8 - #18	#25 - #57
	Connects different bar sizes?	Yes	Yes	Yes	Yes	Yes	Yes
#18 [#57] coupling sleeve/splice installation requirements	Clear space between adjacent splices	N/A	N/A	N/A	N/A	1.50	38
	Minimum dowel projection	N/A	N/A	N/A	N/A	N/A	N/A
	Sleeve length	N/A	N/A	N/A	N/A	5.50	140
	Maximum sleeve diameter	N/A	N/A	N/A	N/A	3.63	92
#14 [#43] coupling sleeve/splice installation requirements	Clear space between adjacent splices	N/A	N/A	N/A	N/A	1.00	25
	Minimum dowel projection	N/A	N/A	N/A	N/A	N/A	N/A
	Sleeve length	N/A	N/A	N/A	N/A	4.25	108
	Maximum sleeve diameter	N/A	N/A	N/A	N/A	2.75	70
#11 [#36] coupling sleeve/splice installation requirements	Clear space between adjacent splices	1.00	25	0+++	0+++	1.00	25
	Minimum dowel projection	0	0	0	0	N/A	N/A
	Sleeve length	4.50	114	4.38	111	3.63	92
	Maximum sleeve diameter	2.00	51	1.94	49	2.25	57
#8 [#25] coupling sleeve/splice installation requirements	Clear space between adjacent splices	0.75	19	0+++	0+++	1.00	25
	Minimum dowel projection	0	0	0	0	N/A	N/A
	Sleeve length	3.00	76	3.13	79	2.75	70
	Maximum sleeve diameter	1.50	38	1.38	35	1.63	41
Bar end preparation	Cut square within 1½°?	No	No	No	No	No	No
	Special cleaning?	No	No	No	No	No	No
	Pre-drying/heating?	No	No	No	No	No++	No++
	Thread cutting?	Yes	Yes	Yes+	Yes+	No	No
	Bar-end check?	No	No	No	No	No	No
	Special coating removal (epoxy, zinc)?	No	No	No	No	No	No
Installation tools	Hand held tools adequate?	Yes	Yes	Yes	Yes	Yes	Yes
	Special tools required?	No	No	No	No	No*	No*

+Bar end threading normally done by Bar Fabricator.
++Bar end threaded by Splice Manufacturer.
+++Flange removed.
*Friction weld made by Splice Manufacturer.

Compression-Only Mechanical Splices

The use of end-bearing to transfer compression from bar to bar requires that the ends of the rebars be saw cut within 1-1/2° of square to the longitudinal axis of the rebars. In field assembly, such mechanical splices must fit within 3° when erected. Commercial devices are used to ensure concentric bearing.

Illustrations of four proprietary end-bearing mechanical splices are shown. Also see Table 37. For more information consult the manufacturers, Appendix C.

Fig. 19(a)—Erico

Fig. 19(b)—Harris

Fig. 19(c)—Erico

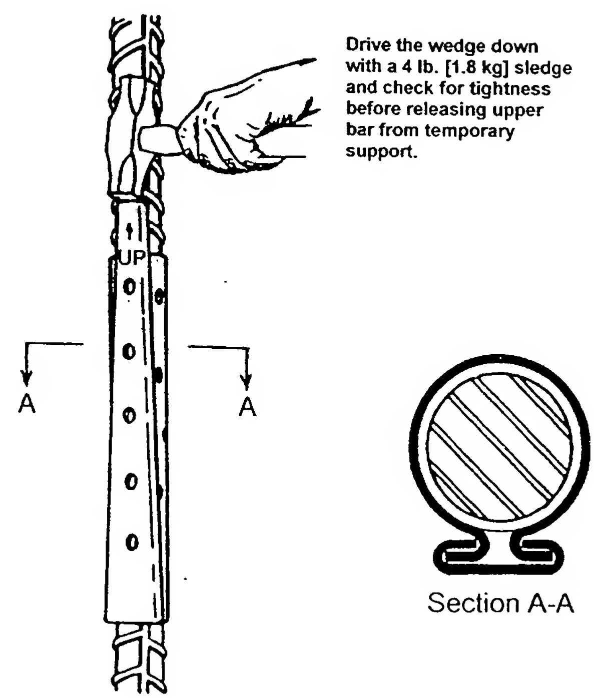


Fig. 19(d)—BarSplice

Table 37—Compression-Only Mechanical Splices

	Description	Bolted Strap Coupling Sleeve				Steel-Filled Coupling Sleeve		Wedge-Locking Coupling Sleeve	
	Manufacturer	Erico		Harris		Erico		BarSplice	
	Figure	19(a)		19(b)		19(c)		19(d)	
Units		in.	mm	in.	mm	in.	mm	in.	mm
Coupling sleeve/splice	Bar size range	#7 - #18	#22 - #57	#8 - #18	#25 - #57	#11 - #18	#36 - #57	#7 - #18	#22 - #57
	Connects different bar sizes?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
#18 [#57] coupling sleeve/splice installation require-ments	Clear space between adjacent splices	3.38	86	2.38	60	3.38	86	3.38	86
	Minimum dowel projection	6.00	152	6.00	152	1.88	48	8.00	203
	Sleeve length	12.00	305	12.00	305	3.00	76	12.00	305
	Maximum sleeve diameter	4.00	102	2.75	70	3.25	83	2.75	70
#14 [#43] coupling sleeve/splice installation require-ments	Clear space between adjacent splices	2.50	64	2.50	64	2.50	64	2.50	64
	Minimum dowel projection	5.50	140	3.50	89	1.88	48	7.00	178
	Sleeve length	11.00	279	7.00	178	3.00	76	10.00	254
	Maximum sleeve diameter	3.00	76	2.25	57	2.50	64	2.00	51
#11 [#36] coupling sleeve/splice installation require-ments	Clear space between adjacent splices	2.13	54	2.13	54	2.13	54	2.13	54
	Minimum dowel projection	4.00	102	3.00	76	1.88	48	6.00	152
	Sleeve length	8.00	203	6.00	152	3.00	76	8.00	203
	Maximum sleeve diameter	3.00	76	1.75	44	2.50	64	1.63	41
#8 [#25] coupling sleeve/splice installation require-ments	Clear space between adjacent splices	1.50	38	1.50	38	N/A	N/A	1.50	38
	Minimum dowel projection	3.00	76	3.00	76	N/A	N/A	4.75	121
	Sleeve length	6.00	152	6.00	152	N/A	N/A	5.50	140
	Maximum sleeve diameter	2.25	57	1.38	35	N/A	N/A	1.38	35
Bar end preparation	Cut square within 1½°?	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes
	Special cleaning?	No	No	No	No	Remove concrete & loose rust		No	No
	Pre-drying/heating?	No	No	No	No	Yes	Yes	No	No
	Thread cutting?	No	No	No	No	No	No	No	No
	Bar-end check?	No	No	No	No	Yes	Yes	No	No
	Special coating removal (epoxy, zinc)?	No	No	No	No	Yes	Yes	No	No
Installation tools	Hand held tools adequate?	Yes	Yes	Yes	Yes	No	No	Yes	Yes
	Special tools required?	No	No	No	No	Yes	Yes	No	No

Dowel Bar Mechanical Splice Systems

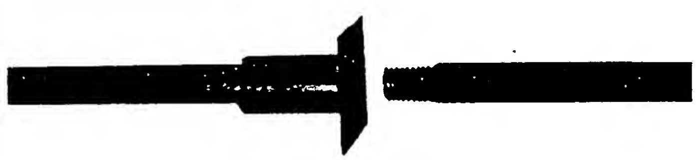


Fig. 20(a)—BarSplice

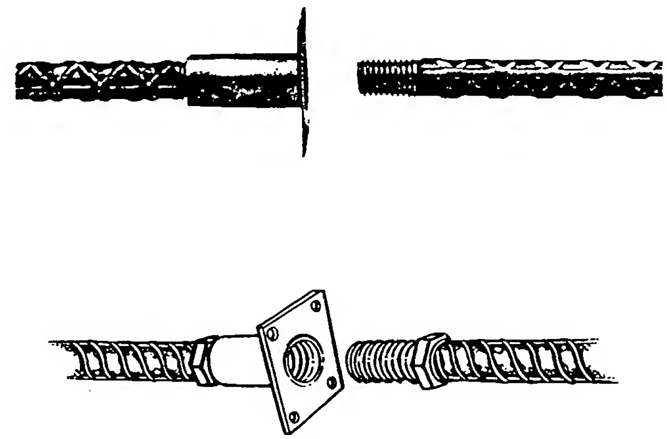


Fig. 20(b)—Dayton

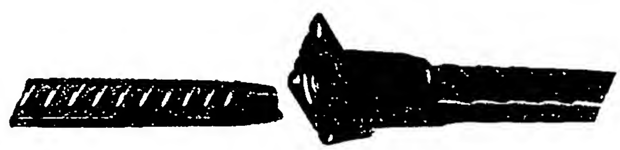


Fig. 20(c)—Erico

Fig. 20(d)—Richmond

Dowel bar mechanical splices are used to prevent rebars from penetrating or protruding from forms and reinforced concrete structures.

All of the various systems available consist of several components. The coupling component is internally threaded and another component is externally threaded. The internally threaded component is normally designed to fasten directly to the form face and is usually encased in the first concrete placement. These systems are available in a variety of designs, configurations, sizes, and shapes. For more information consult the manufacturers, Appendix C.

3.3 WELDED SPLICES

Welding Processes and Materials

Electric arc welding is the only commonly used manual welding process in the field. All welding should conform to ANSI/AWS D1.4-92 "Structural Welding Code—Reinforcing Steel" of the American Welding Society.*

The most widely used type of reinforcing bars is billet-steel conforming to ASTM A615/A615M. Usage of low-alloy steel bars per ASTM A706/A706M is increasing. The "weldability" of steel established by its chemical composition limits the applicable welding procedures and establishes preheat requirements.**

Tack Welding

Connection of crossing bars by small arc welds, known as "tack welds," is not recommended. Unless these welds are made in conformance with all requirements of ANSI/AWS D1.4-92, they tend to cause a metallurgical "notch" effect and may affect the strength of the bars.

Numerous reports from field practice have identified tack-welded points as a factor associated with brittle failure of reinforcing bar assemblies by accidental impacts during rough handling. Tests on some reinforced concrete members containing laboratory-made tack-welded assemblies have been aborted by premature failure at tack-welded points. At least one welder's qualification test for butt-welding a large bar has been aborted by premature failure at a point outside the weld where the welder merely tested the circuit leaving a bit of electrode, similar in effect to a tack-weld. Few tests on the effect of tack-welding as such have been reported. The user is referred to "Fatigue Tests of Reinforcing Bar—Tack Welding of Stirrups." K. T. Burton and E. Hognestad, ACI Journal, May 1967, V. 64. p. 244. Tack welding seems to be particularly detrimental to ductility (impact resistance), to fatigue resistance, and, to a lesser extent, to static yield strength and ultimate strength. Where a small bar is tack welded to a larger bar, the detrimental "notch" effect is exaggerated in the large bar. Fast cooling under cold weather conditions is likely to aggravate these effects.

---

*Available from American Welding Society, P. O. Box 351040, 2501 NW 7th, Miami, Florida 33125.

**Chemical analysis are not ordinarily meaningful for rail-steel (ASTM A616/A616M) and axle-steel (ASTM A617/A617M) reinforcing bars. Welding of these types of bars is not recommended.

4.1 RESPONSIBILITY

The entire responsibility for designing and specifying splices rests upon the Architect/Engineer. Only the party familiar with the structural analysis, probable construction conditions, and final conditions of service can properly evaluate the variables to determine the most efficient and economical splice method. The following discussion is provided to help the Architect/Engineer in this task.

Cast-in-place construction traditionally uses lap splices for horizontal and vertical bars where the bar size is #11 [#36] or smaller. #11 [#36] and smaller bars are sometimes mechanically-spliced or butt-welded. #14 and #18 [#43 and #57] bars must be mechanically-spliced or butt-welded, whether horizontal or vertical; lap splices are not permitted except for compression only to smaller footing dowels. In precast concrete construction, lap and butt splices are used, including lap-welded splices for smaller bars.

4.2 CONSIDERATIONS IN SELECTION OF SPLICE METHOD

Lap splices can cause congestion at the splice locations, and can make their use impractical. In column design, consideration should also be given to the fact that lapped offset bars may have to extend inside the bars above and, therefore, reduce the moment arm in bending. In precast concrete construction, lack of space between members may preclude use of lap splices. The traditional lap splice, when it will satisfy all requirements, is generally the most economical.

The decision whether to use lap splices or mechanical splices in the larger bar sizes is based partially on economics and partially on design or practical considerations. First, compare the cost of the additional lap material, plus the fact that the column bars must be offset bent (subject to fabricating bending extra), to a mechanical splice that may require end preparation of the bar, plus the cost of splicing material, plus installation, all complicated by the variety of available mechanical splices. Full mechanical splices provide at least 125 per cent of the specified minimum yield strength of the bars. Proprietary mechanical splices are generally available for compression splices as well as for minimum ultimate tensile strength splices. End-bearing mechanical splices for compression applications are available.

Design of reinforced concrete structures in seismic areas requires special consideration for splices. Seismic design requirements are covered in "Chapter 21—Special Provisions for Seismic Design" in the ACI Building Code. These provisions apply to special ductile frames and shear walls.*

*For ductile frame detailing, see text and examples in the ACI Detailing Manual, 1994 by ACI Committee 315.

For all horizontal splices in girders, and splices in columns resisting large bending moments compared to vertical loads, in which lap splices are not feasible, mechanical splices or butt-welded splices are required.

5.1 LAP SPLICES OF BARS #11 [#36] OR SMALLER FOR COMPRESSION ONLY

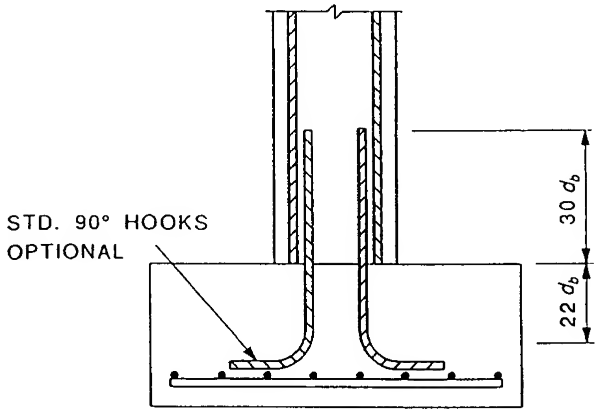
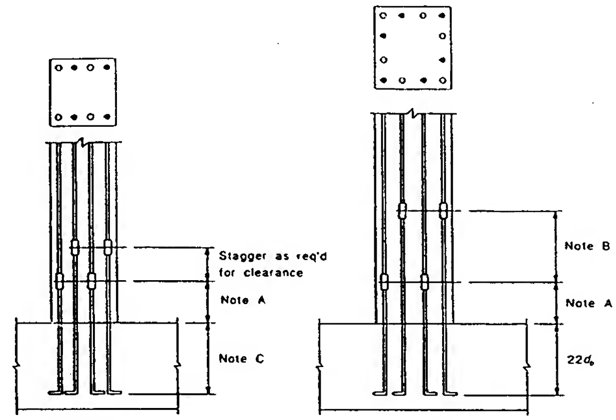


Fig. 21—Compression Lap Splices for Dowels

Notes:

1. In shallow footings, standard 90° end hooks may be used as a convenience only to support dowels as shown. Hooks do not add to the compression development. See ACI 12.5.5.
2. Where the required compression development length for bars is considerably less than the distance available to the bottom reinforcement, it will usually be more practical to suspend the short straight dowels from a template.

5.2 MECHANICALLY-SPLICED DOWELS; VARIOUS METHODS APPLICABLE TO ALL SIZES OF COLUMN BARS



Mechanical Splices For Tension or Compression

End-Bearing Mechanical Splices For Compression Only

Note A: Approximately 24 in. [600 mm] for convenience in installation of mechanical splices.
Note B: Minimum 0.5ℓ_d (tension development length). Stagger alternate bars.
Note C: Embedment (anchorage) as required for tension or compression.

Fig. 22—Mechanically-Spliced Dowels

Notes:

1. With all types of mechanical splices, the elevation of top of dowel should be shown. End preparation should be indicated, i.e., square-cut, chisel cut, flame cut, or sheared. Dowels should be preset with a template and be plumb.
2. Where some arrangement of stagger is required, a cross-section plan view with dowel heights located and identified is required. Show north arrow for direction.
3. Mechanically-spliced vertical bars as shown will require free-standing erection and tie assembly. Follow the ACI Detailing Manual recommendations for tie arrangements suitable for free-standing assembly. If design conditions permit mechanical splices of all bars at one point, without stagger, the use of preassembled cages of column reinforcement will simplify field erection.
4. End-bearing mechanical splices are usually practical only where the maximum tensile stress in the bar is 0.5 f_y or less and at least half the bars are staggered, where tension lap splices would be Class A. Minimum stagger of 2 ft [600 mm] is recommended. This length is ample for practical erection clearances and provides approximately 35 per cent of the Class A tension lap for #11 [#36] bars, and more for smaller bars. The 2 ft [600 mm] minimum stagger provides approximately 20 per cent of the tension development length (ℓ_d) for #18 [#57] bars and should be ample for such bars where stress is always compressive.

5.3 FLUSH CONNECTIONS FOR FUTURE DOWELS

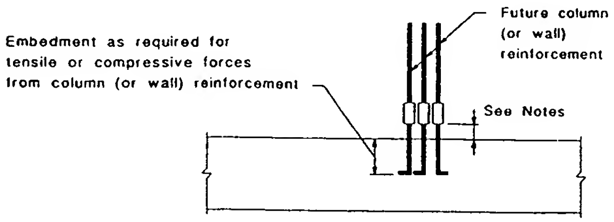


Fig. 23—Flush Dowel Connections

Notes:

1. Where construction convenience indicates, or where additional floors are to be added to an existing building, the required minimum length for stub dowels varies for different mechanical splices. Manufacturer's recommendations are available, see Appendix C.
2. Some mechanical splices can be installed below the surface—their tops flush with the surface. See individual devices shown in this publication, and consult manufacturers. See Appendix C.

5.4 HEADED REINFORCING BARS

An alternate, effective way to fully anchor or develop rebars in tension within relatively short embedment lengths is to use headed reinforcing bars rather than bars with standard hooks. Headed rebars consist of a nut or plate, having either a round, elliptical or rectangular shape, attached to the end(s) of the bar. Attachment of the head to the rebar is accomplished by welding, threading or swaging. Another configuration of a headed rebar is a bar with an integrally-forged head.

Since headed rebars are intended to replace bars with standard end hooks, the benefits of such an anchorage system are to reduce embedment and simplify bar placement. Headed bars were first used in the construction of reinforced concrete offshore oil platforms. Usage of headed bars has been extended to bridge and building construction.

At press time for this publication, ASTM had approved specification A970/A970M for headed bars; and ACI Committee 318 was planning to introduce design requirements for headed bars in the next edition of the ACI 318/318M Code.

6.1 END-BEARING MECHANICAL SPLICES

The arrangement of bars in a column should be shown on the design drawings, considering:

(a) That the fewer the splices at any point, the greater the capacity to resist moment;

(b) That a logical and, where possible, symmetrical pattern of bars should remain after the number of bars is reduced in the upper stories of a building.

The stagger arrangement, as shown in the sample column schedule, is preferred where column moments do not control the design, where one or two unspliced bars in each face is sufficient at a splice point, and where the two-story bar lengths can be located near the inflection point where there is little or no moment. Even if single-story bar lengths are preferred, both splice points can be near the inflection point. See Fig. 24.

The stagger arrangement also applies to bars in spirally- reinforced columns.

6.2 TENSION-COMPRESSION MECHANICAL SPLICES OR BUTT-WELDED SPLICES

Two arrangements are shown suitable for tension-compression mechanical splices. If compressive stress is critical, the splices need not be staggered. In the "no stagger" arrangement, the convenience of preassembled cages will often outweigh the cost of additional splices. See Fig. 25.

A distance of 2 ft [600 mm] above the floor line (point of maximum rebar stress) is shown as a minimum to avoid locating splices at the point of maximum stress. It is also a practical convenience for attachment of temporary clamps during installation of some splices.

The stagger arrangement reduces the number of splices by 50 percent and will often permit the use of splices more economical than those designed for 125% f_y. See ACI 12.17.2.1 and ACI 12.17.2.2.

The suggested sample column schedules shown are for design drawings. Similar schedules would be shown by the reinforcing steel detailer on the placing drawings.

Always show direction arrow next to the column plan to aid in setting dowels and for splices.

Note: Bar sizes #14 and #18 [#43 and #57] may be lap spliced only for compression and only to #11 [#36] or smaller bars (ACI 12.16.2). See Fig. 26.

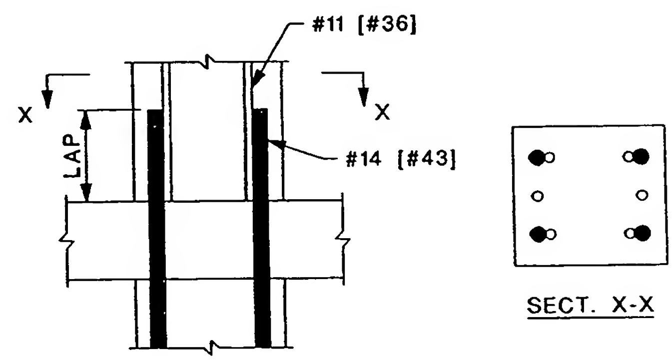


Fig. 26—Lapping #14 or #18 [#43 or #57] Bars

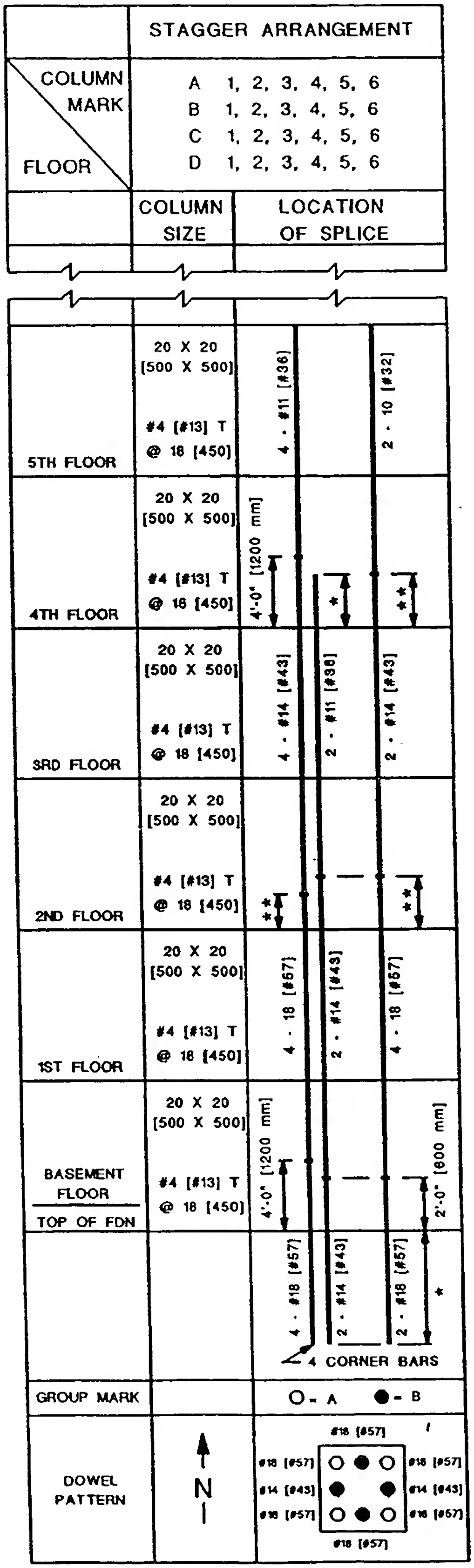


Fig. 24.—End-Bearing Mechanical Splices

Note:

Following dimensions must be supplied by Architect/Engineer.

*—A_s required to develop design compressive stress and required minimum tensile stress in bar. See ACI 12.17.

**—A_s required to develop the difference in capacity of bars.

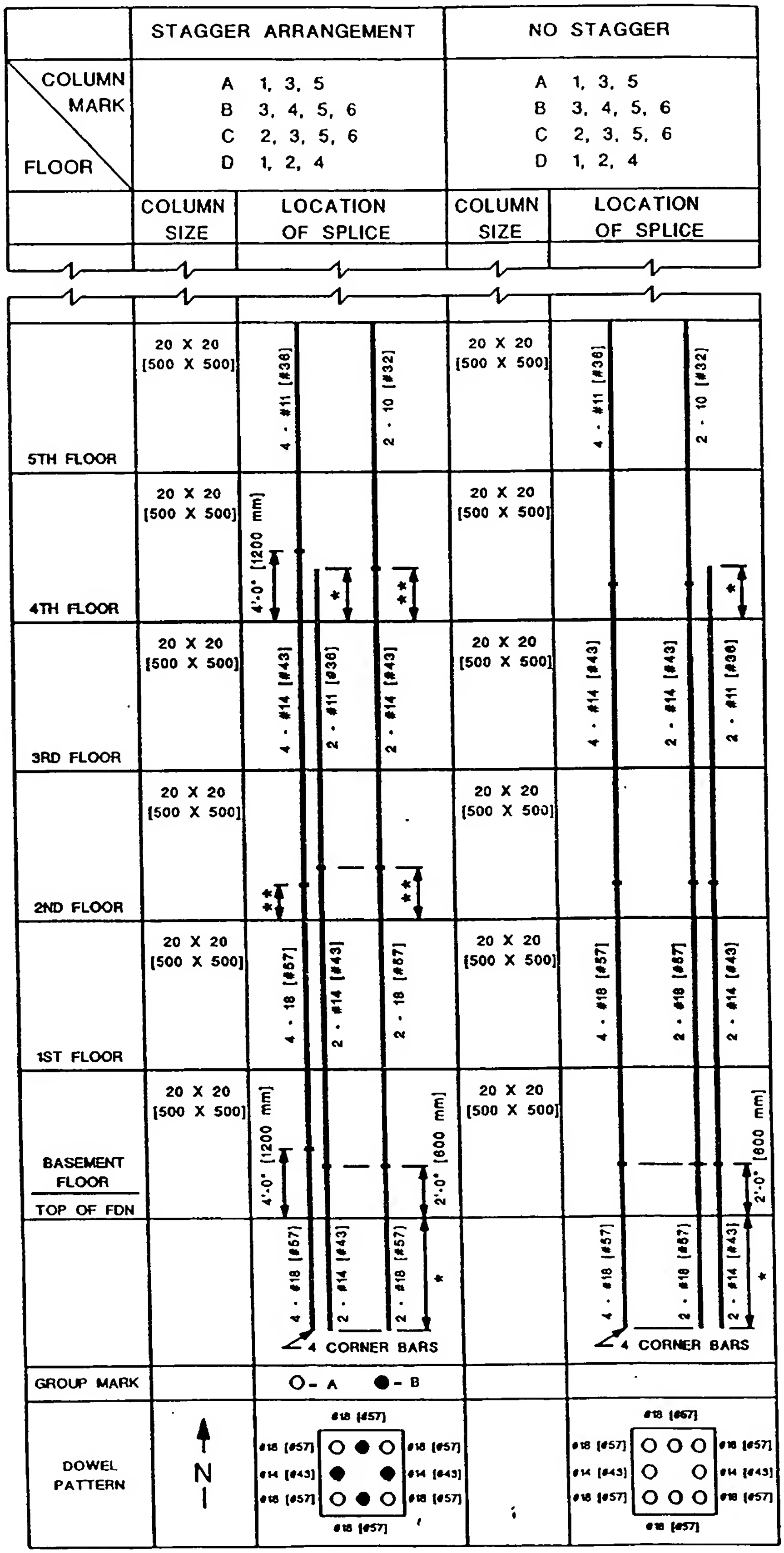


Fig. 25—Tension-Compression Mechanical Splices or Butt-Welded Splices

Notes:

1. Column ties: #4 @ 4 [#13 @ 100] for top and bottom third, #4 @ 8 [#13 @ 200] for middle third.
2. Following dimensions must be supplied by Architect/Engineer.

   *—As required to develop design stress in bar.

   **—As required to develop the difference in capacity of bars.

Horizontal splices occur in cast-in-place reinforced concrete members for two reasons: (1) to provide for construction joints, temporary or permanent, and (2) to provide for continuity in rebars that are too long to furnish in one piece. Lap splices are used predominantly. Mechanical splices are primarily limited to bar sizes #11 [#36] and larger in heavily reinforced mats, columns, or possibly even beams. Lap splices may be in contact or spaced, but preferably in contact. Splices are usually staggered to prevent concentration in one plane. Unless staggered, tension lap splices are required to meet increasingly severe criteria.

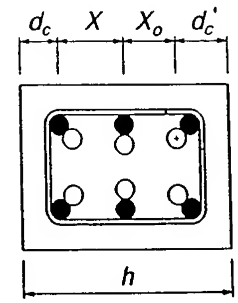
Horizontal splices are almost always necessary in precast concrete construction. These splices are usually mechanically-spliced, butt-welded or lap-welded. For welded splices, it is necessary to know the chemical composition of the bars being welded.

Vertical splices occur in cast-in-place members for essentially the same reasons as for horizontal splices. Lap splices are generally used for bar sizes #11 [#36] and smaller, except that in heavily-reinforced columns, #11 [#36] and smaller bars are frequently mechanically-spliced. Generally, column splices are made at floor level. An entire column cage (vertical bars and ties or spirals) can then be preassembled and set into place. If lap splices are used in critical tension areas, increased lap lengths or spirals or ties must be provided in these locations. When lap splices are provided, the bars that extend up from below may have to come inside of the bars above. When mechanical splices are used, it is necessary to have the bar from below extend up directly under the bar above to which it is to be spliced. See Figs 27 and 28.

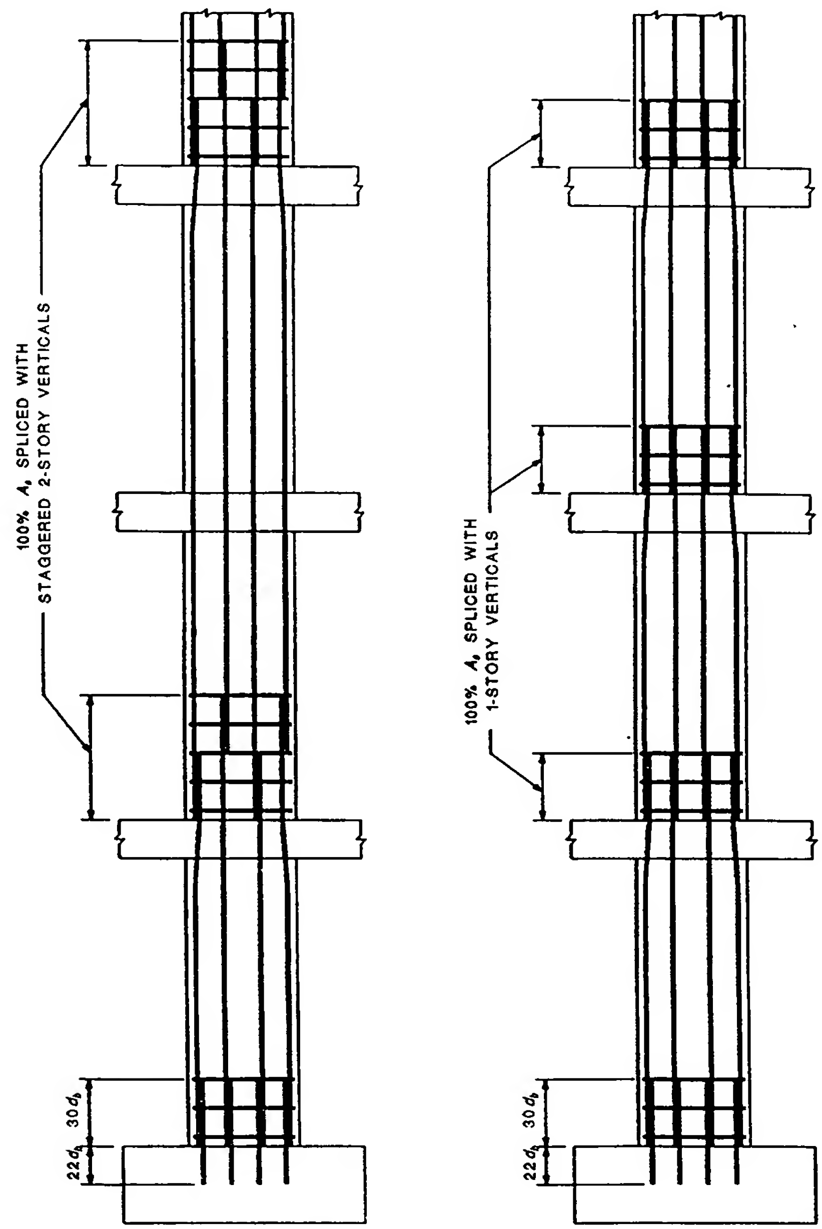
When larger columns with many #14 or #18 [#43 or #57] bars are used, a column cage with 4 to 8 vertical bars and its ties or spirals is first set and spliced to the vertical column bars from below. Thereafter, the remaining vertical bars are individually lowered inside the column cage and spliced. Erection with staggered splices, multi-story lifts and large size bars may be complicated by certain column tie arrangements. See "Details and Detailing of Concrete Reinforcement," ACI Detailing Manual for recommended tie arrangements.

Another point often overlooked in design for lap splices of offset column vertical bars is the reduction in effective depth of the offset bars. This effect can usually be safely neglected when the stress is always compressive with low steel ratios. Particularly with steel ratios in excess of 0.04 and large moments, nominal capacity should be reduced. A quick approximation for this reduction is:

$R = A_s f_y \, (X\text{-}Xo)/X$
where R = reduction of moment capacity.
$X_O = 0.5h\text{-}d'_C$ for offset bar, and
$X = 0.5h\text{-}d_C$ for straight bar



Where column size above is unchanged from that below, "upside down" offset bars are effective to maintain the full moment capacity at column splices. In U.S. practice, this detail is very rate, and should be fully illustrated on structural drawings to avoid misunderstandings, whenever its use is deemed necessary.



(a) Vertical Bars, 2-Stories Long

(b) Vertical Bars, 1-Story Long (Usually Erected as Preassembled Cage)

Fig. 27—Typical Tied Column, #11 [#36] Bars or Smaller

Notes:

1. Assumed factored moments above base cause bar tension and factored moment at base=0.
2. For most practical designs for ϕP_n maximum at $0.80\phi P_o$, tensile $f_s < 0.5 f_y$. Only in special cases with large eccentricities for high wind moments will tensile A_s furnished $\leq 2A_s$ required.

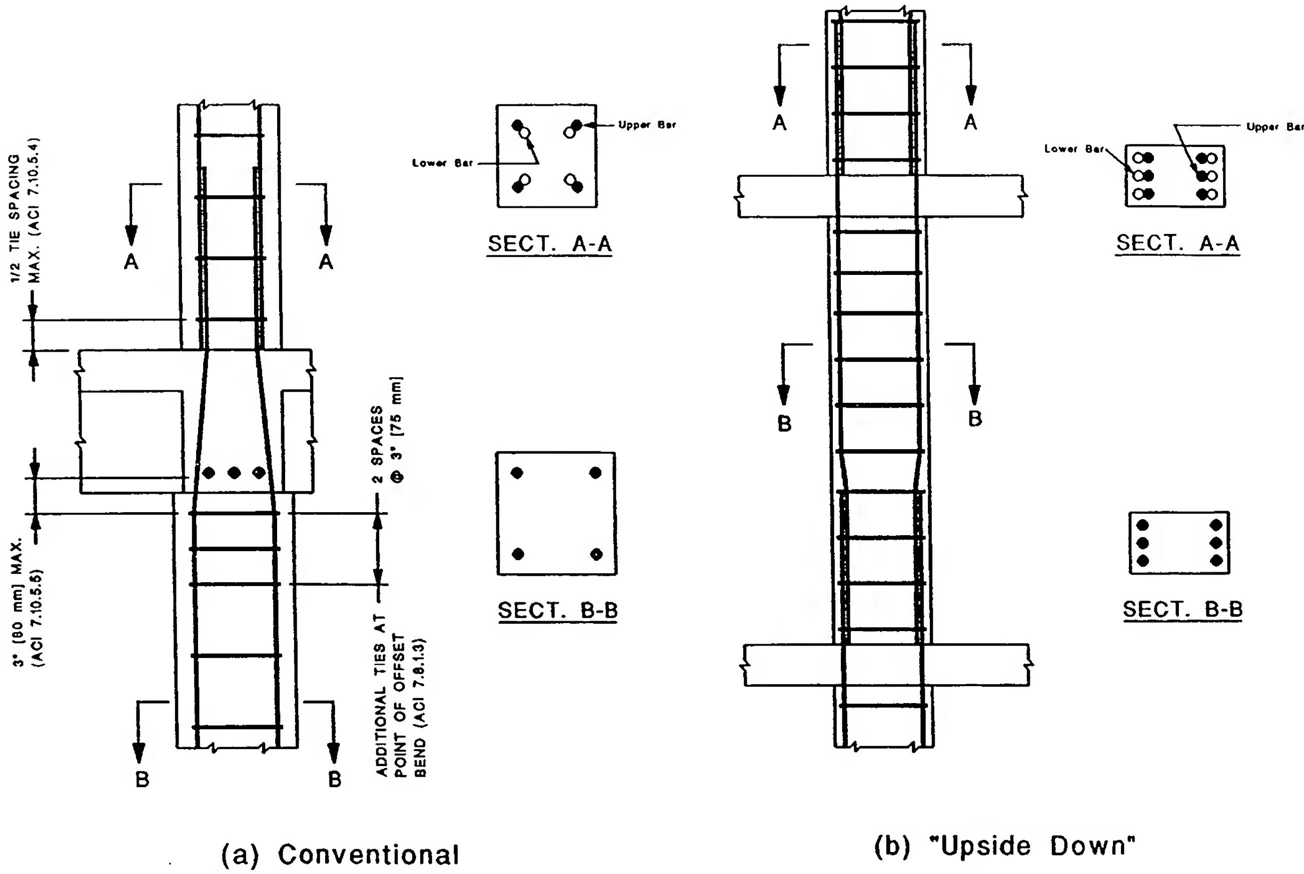


Fig. 28—Columns with Bending Moments, #11 [#36] Bars or Smaller

Notes:

1. For compression-controlled lap splices, use lap length 30 d_b unless otherwise designed as special.
2. For tension-controlled lap splices, provide Class of lap as specified by Architect/Engineer. Lap lengths per tables.
3. When lap splicing bars of different sizes, the length of lap is determined as required: lap for smaller bar, but may not be less than required embedment of larger bar.

A.1 TENSION DEVELOPMENT LENGTH—ACI 12.2.2

Step 1: SQRFC = Smaller of 100 or $\sqrt{f_c'}$ (ACI 12.1.2)
[SQRFC = Smaller of 25/3 or $\sqrt{f_c'}$ (ACI 12.1.2)]

Step 2: Calculate development length (ACI 12.2.2)

ℓ_{db} = d_b (1/25) f_y/SQRFC (#6 bar and smaller and deformed wire)
[d_b (12/25) f_y/SQRFC (#19 bar and smaller and deformed wire)]

= d_b (1/20) f_y/SQRFC (#7 bar and larger)
[d_b (3/5) f_y/SQRFC (#22 bar and larger)]

Step 3: Calculate concrete cover and c.-c. spacing expressed as multiples of bar diameter, d_b.

Step 4: Refer to chart below to determine whether Case 1 or Case 2:

STRUCTURAL ELEMENT	CONCRETE COVER	CASE, ACCORDING TO CENTER-TO-CENTER BAR SPACING		
		$<2d_b$	$\geq 2d_b$ $<3d_b$	$\geq 3d_b$
Beams, Columns	$<d_b$	2	2	2
	$\geq d_b$	2	1	1
All Others	$<d_b$	2	2	2
	$\geq d_b$	2	2	1

Where d_b = nominal diameter of bar.

Step 5: Apply cover/spacing modification factor:

CASE	ℓ_d =
1	1.0 x ℓ_d
2	1.5 x ℓ_d

Step 6: Lightweight aggregate concrete (ACI 12.2.4)

If f_{ct} not specified, ℓ_d = 1.3 ℓ_d
If f_{ct} is specified, ℓ_d = Factor x ℓ_d

Where Factor ≥ 6.7 SQRFC/f_{ct} ≥ 1.0 [SQRFC /(1.8f_{ct}) ≥ 1.0]

Step 7: Top bar effect and epoxy coating (ACI 12.2.4)

	Top Bar	Not Top Bar
Uncoated	$\ell_d = 1.3 \times \ell_d$	$\ell_d = 1.0 \times \ell_d$
Epoxy-Coated	$\ell_d = 1.7 \times \ell_d$	$\ell_d = 1.5 \times \ell_d$

Step 8: Minimum length (ACI 12.2.1)

$\ell_d \geq 12$ in. [300 mm]

A.2 TENSION DEVELOPMENT LENGTH—ACI 12.2.3

Step 1: SQRFC = Smaller of 100 or $\sqrt{f_c'}$ (ACI 12.1.2)
[SQRFC = Smaller of 25/3 or $\sqrt{f_c'}$ (ACI 12.1.2)]

Step 2: Calculate c, A_{tr} and K_{tr} (ACI 12.2.3)

c = smaller of:
a. Distance from center of bar to nearest concrete surface.
b. One-half the center-to-center distance spacing of the rebar.

A_{tr} = Total cross-sectional area of all transverse reinforcement within spacing s, in.^{2} [mm^2]

$$K_{tr} = \frac{A_{tr} f_{yt}}{1500\, sn} \quad \left[\frac{A_{tr} f_{yt}}{10\, sn}\right]$$

Where f_{yt} = specified yield strength of transverse reinforcement, psi [MPa].
s = spacing of transverse reinforcement, inches [mm].
n = number of bars being developed or spliced.

Note: $(c + K_{tr})/d_b \leq 2.5$

Step 3: Calculate development length (ACI 12.2.3)

$$\ell_d = (3/40)(f_y/\text{SQRFC})d_b / \left(\frac{c + K_{tr}}{d_b}\right)$$

$$[(9/10)(f_y/\text{SQRFC})d_b / \left(\frac{c + K_{tr}}{d_b}\right)]$$

Step 4: Lightweight aggregate concrete (ACI 12.2.4)

If f_{ct} is not specified, $\ell_d = 1.3\, \ell_d$

If f_{ct} is specified, ℓ_d = Factor x ℓ_d

Where Factor $\geq$ 6.7 SQRFC $/f_{ct} \geq 1.0$ [SQRFC$/(1.8 f_{ct}) \geq 1.0$]

Step 5: Top bar effect and epoxy coating (ACI 12.2.4)

	Top Bar	Not Top Bar
Uncoated	$\ell_d = 1.3 \times \ell_d$	$\ell_d = 1.0 \times \ell_d$
Epoxy-Coated	$\ell_d = 1.7 \times \ell_d$	$\ell_d = 1.5 \times \ell_d$

Step 6: Bar size (12.2.4)

If #6 [#19] and smaller and deformed wire, $\ell_d = 0.8\ \ell_d$

If #7 [#22] and larger, $\ell_d = 1.0\ \ell_d$

Step 7: Minimum length (ACI 12.2.1)

$\ell_d \geq$ 12 in. [300 mm]

A.3 TENSION DEVELOPMENT LENGTH—AASHTO

Step 1: Basic development length (AASHTO 8.25.1)

ℓ_{db}	= Greater of $0.04\,A_b f_y/\sqrt{f_c'}$ or $0.0004\,d_b f_y$	(#3-#11)
	= [Greater of $0.02\,A_b f_y/\sqrt{f_c'}$ or $0.06\,d_b f_y$	(#10-#36)]
	= $0.085\,f_y/\sqrt{f_c'}$	(#14)
	= [$25\,f_y/\sqrt{f_c'}$	(#43)]
	= $0.11\,f_y/\sqrt{f_c'}$	(#18)
	= [$34\,f_y/\sqrt{f_c'}$	(#57)]

Step 2: Lightweight aggregate concrete (AASHTO 8.25.2.2)

If f_{ct} is not specified, $\ell_d = 1.33\ \ell_{db}$

If f_{ct} is specified, ℓ_d = Factor x ℓ_{db}

Where Factor = $6.7\sqrt{f_c'}/f_{ct} \geq 1.0$ $[\sqrt{f_c'}/(1.8 f_{ct}) \geq 1.0]$

Step 3: Top bar effect and epoxy coating (AASHTO 8.25.2.1, 8.25.2.3)

	Top Bar	Not Top Bar
Uncoated	$\ell_d = 1.4 \times \ell_d$	$\ell_d = 1.0 \times \ell_d$
Epoxy-Coated	$\ell_d = 1.7 \times \ell_d$	$\ell_d = 1.5 \times \ell_d$

Step 4: If extra cover/spacing in accordance with AASHTO 8.25.3.1

$\ell_d = 0.8\ \ell_d$ (i.e. Category 1)
Otherwise, $\ell_d = 1.0\ \ell_d$ (i.e. Category 2)

Step 5: If spirals in accordance with AASHTO 8.25.3.3

$\ell_d = 0.75\ \ell_d$

Step 6: Minimum length (AASHTO 8.25.4)

$\ell_d \geq 12$ in. [300 mm]

A.4 COMPRESSION DEVELOPMENT LENGTH—ACI 318, AASHTO

Step 1: SQRFC = Smaller of 100 or $\sqrt{f_c'}$ (ACI 318 only, ACI 12.1.2)
[SQRFC = Smaller of 25/3 or $\sqrt{f_c'}$ (ACI 318 only, ACI 12.1.2)]

Step 2: Basic development length (ACI 12.3.2, AASHTO 8.26.1)

$\ell_{db} =$ Greater of 0.02 $d_b f_y$/SQRFC or 0.0003 $d_b f_y$
[Greater of $d_b f_y$/(4 SQRFC) or 0.04 $d_b f_y$]

Step 3: If spirals or ties in accordance with ACI 12.3.3.2 (AASHTO 8.26.2.2)

$\ell_d = 0.75\ \ell_{db}$

Step 4: Minimum length (ACI 12.3.1, AASHTO 8.26)

$\ell_d \geq 8$ in. [200 mm]

A.5 TENSION DEVELOPMENT LENGTH OF STANDARD HOOKS—ACI 318, AASHTO

Step 1: SQRFC = Smaller of 100 or $\sqrt{f_c'}$ (ACI 318 only, ACI 12.1.2)
[SQRFC = Smaller of 25/3 or $\sqrt{f_c'}$ (ACI 318 only, ACI 12.1.2)]

Step 2: Basic development length (ACI 12.5.2, AASHTO 8.29.2)

$\ell_{hb} = 1200\ d_b$/SQRFC [100 d_b/SQRFC]

Step 3: If f_y not 60,000 psi [420 MPa] (ACI 12.5.3.1, AASHTO 8.29.3.1)

$\ell_{dh} = (f_y / 60{,}000)\ \ell_{hb}\ [(f_y / 420)\ \ell_{hb}]$

Step 4: If extra cover in accordance with ACI 12.5.3.2 (AASHTO 8.29.3.2)

$\ell_{dh} = 0.7\ \ell_{dh}$

Step 5: If ties/stirrups in accordance with ACI 12.5.3.3 (AASHTO 8.29.3.3)

$$\ell_{dh} = 0.8\ \ell_{dh}$$

Step 6: If lightweight aggregate concrete (ACI 12.5.3.5, AASHTO 8.29.3.5)

$$\ell_{dh} = 1.3\ \ell_{dh}$$

Step 7: If epoxy-coated (ACI 12.5.3.6, AASHTO 8.29.3.6)

$$\ell_{dh} = 1.2\ \ell_{dh}$$

Step 8: Minimum length (ACI 12.5.1, AASHTO 8.29.1)

$$\ell_{dh} \geq 8\ d_b,\ 6\text{ in. [150 mm]}$$

A.6 TENSION LAP SPLICE LENGTH—ACI 318

Step 1: Calculate tension development length (see Section A.1 or B.2)

Step 2: Lap Class (ACI 12.15.1)

If Class A, LAP = ℓ_d
If Class B, LAP = 1.3 ℓ_d

Step 3: Minimum length (ACI 12.15.1)

LAP $\geq$ 12 in. [300 mm]

A.7 TENSION LAP SPLICE LENGTH—AASHTO

Step 1: Calculate tension development length (see Section A.3)

Step 2: Lap Class (AASHTO 8.32.3.1)

If Class A, LAP = ℓ_d

If Class B, LAP = 1.3 ℓ_d

If Class C, LAP = 1.7 ℓ_d

Step 3: Minimum length (AASHTO 8.32.3.1)

LAP $\geq$ 12 in. [300 mm]

A.8 COMPRESSION LAP SPLICE LENGTH—ACI 318, AASHTO

Step 1: Basic lap length (ACI 12.16.1, AASHTO 8.32.4.1)

If $f_y \le 60{,}000$ psi, LAP $= 0.0005 f_y d_b$
[If $f_y \le 420$ MPa, LAP $= 0.07 f_y d_b$]

If $f_y > 60{,}000$ psi, LAP $= (0.0009 f_y - 24)\, d_b$
[If $f_y > 420$ MPa, LAP $= (0.13 f_y - 24)\, d_b$]

Step 2: Minimum length (ACI 12.16.1, AASHTO 8.32.4.1)

LAP $\ge$ 12 in. [300 mm]

Step 3: If $f_c' < 3000$ psi [20 MPa] (ACI 12.16.1, AASHTO 8.32.4.1)

LAP = (4/3) LAP

Step 4: Compression member and minimum length

If tied compression member in accordance with ACI 12.17.2.4 (AASHTO 8.32.4.1)

LAP = 0.83 x LAP

$\ge$ 12 in. [300 mm]

If spiral compression member in accordance with ACI 12.17.2.5 (AASHTO 8.32.4.1)

LAP = 0.75 LAP

$\ge$ 12 in. [300 mm]

A.9 SEISMIC JOINT TENSION DEVELOPMENT LENGTH—ACI 318

Step 1: Basic development length (ACI 21.5.4.1)

ℓ_{db} = Greater of $8\, d_b$, 6 in. [150 mm], or $f_y d_b/(65\sqrt{f_c'})$ [$f_y d_b/(5.4\sqrt{f_c'})$]

Step 2: If lightweight aggregate concrete (ACI 21.5.4.1)

$\ell_d = 1.25\, \ell_{db}$

Step 3: Top bar effect (ACI 21.5.4.2)

If top bar, $\ell_d = 3.5\, \ell_d$

If not top bar, $\ell_d = 2.5\, \ell_d$

A.10 SEISMIC JOINT TENSION HOOK DEVELOPMENT LENGTH—ACI 318

Step 1: Basic hook development (ACI 21.5.4.1)

ℓ_{dh} = Greater of 8 d_b, 6 in., or $f_y\, d_b/(65 \sqrt{f_c'})$
[Greater of 8 d_b, 150 mm, or $f_y\, d_b/(5.4 \sqrt{f_c'})$]

Step 2: If lightweight aggregate concrete (ACI 21.5.4.1)

$\ell_{dh} = 1.25\ \ell_{dh}$

A.11 TENSION DEVELOPMENT LENGTH OF PLAIN WELDED WIRE FABRIC—ACI 12.8

Step 1: SQRFC = Smaller of 100 or $\sqrt{f_c'}$ (ACI 12.1.2)
[SQRFC = Smaller of 25/3 or $\sqrt{f_c'}$ (ACI 12.1.2)]

Step 2: Calculate development length (ACI 12.8)

$\ell_d = 0.27\ (A_w/s_w)(f_y/SQRFC)$
[3.3 $(A_w/s_w)(f_y/SQRFC)$]

Step 3: Lightweight aggregate concrete (ACI 12.2.4)

If f_{ct} not specified, $\ell_d = 1.3\ \ell_d$

If f_{ct} is specified, ℓ_d = Factor x ℓ_d

Where Factor ≥ 6.7 SQRFC/f_{ct} ≥ 1.0 [SQRFC/(1.8 f_{ct})≥ 1.0]

Step 4: Minimum length (ACI 12.8)

$\ell_d \geq$ 6 in. [150 mm]

A.12 TENSION DEVELOPMENT OF DEFORMED WELDED WIRE FABRIC—ACI 12.7

Step 1: Calculate tension development length (see Section A.1 or A.2)

Note: Minimum tension devleopment length is 8 in. [200 mm]

Step 2: Calulate WFF x ℓ_d where WFF = Wire Fabric Factor:

a. If at least one cross-wire within development length and cross-wire is at least 2 in. [50 mm] from critical section:

WFF = Greater of:
$(f_y - 35{,}000)/f_y$, 5 d_b/s_w
[$(f_y - 240)/f_y$, 5d_b/s_w]
≤ 1.0

b. Otherwise:

WFF = 1.0

A.13 TENSION LAP SPLICE LENGTH OF PLAIN WELDED WIRE FABRIC—ACI 12.19

Step 1: Calculate tension development length (see Section A.11)

Note: Ignore minimum tension development length at 6 in. [150 mm].

Step 2: If (A_s provided) is less than (A_s required), lap length is greater of:

- Cross-wire spacing + 2 in. [50 mm]
- 1.5 ℓ_d
- 6 in. [150 mm]

If (A_s provided) is at least (A_s required), lap splice length is greater of:

- 1.5 ℓ_d
- 2 in. [50 mm]

A.14 TENSION LAP SPLICE LENGTH OF DEFORMED WELDED WIRE FABRIC—ACI 12.18

Step 1: Calculate tension development length (see Section A.12)

Note: Ignore minimum tension development length of 8 in. [200 mm].

Step 2: Lap splice length is greater of:

- 1.3 ℓ_d
- 8 in. [200 mm]

The tables on the following four pages give values of tension development lengths of straight bars and tension lap splice lengths based on the provisions in Chapter 12 of the ACI 318-89 Building Code. All tabulated data are for Grade 60 reinforcing bars in normal weight concrete with the concrete compressive strength, f'_c ranging from 3000 to 8000 psi.

The tables use the terminology "Categories 1, 2, 3, 4, 5, and 6." Categories 1 through 6, which depend on the type of structural element, concrete cover, and the center-to-center spacing of the bars, are defined as:

Structural Element	Concrete Cover	Category, According to Center-to-Center Bar Spacing			
		$\leq 3d_b$	$>3d_b$ $<4d_b$	$\geq 4d_b$ $<6d_b$	$\geq 6d_b$
Beams, Columns, and Inner Layer of Walls or Slabs	$\leq d_b$	1	1	1	2
	$>d_b$	1	3	5	6
All Others	$\leq d_b$	1	1	1	2
	$>d_b$, $<2d_b$	1	3	3	4
	$\geq 2d_b$	1	3	5	6

Tables 4(a) through 4(f), tension development lengths, and Tables 5(a) through 5(f), tension lap splice lengths, are for uncoated bars. Tables 6(a) through 6(f) and Tables 7(a) through 7(f) are for epoxy-coated bars. There are no special development requirements in the Code for zinc-coated (galvanized) bars. For lightweight aggregate concrete, the values in the tables would have to be modified by the applicable factor (ACI 12.2.4.2).

These notes apply to all the tabulated values of tension development and tension lap splices:

1. Values of ℓ_d for bars in beams or columns are based on transverse reinforcement meeting minimum requirements for stirrups in ACI 11.5.4 and 11.5.5.3, or meeting tie requirements in ACI 7.10.5; and are based on minimum cover specified in ACI 7.7.1.
2. Top bars are horizontal bars with more than 12 in. of concrete cast below the bars.
3. #11 and smaller edge bars with c.-c. spacing not less than 6 d_b are assumed to have a side cover not less than 2.5 d_b. Otherwise, Category 5 applies rather than Category 6.
4. Conditions which require Category 1 or Category 2 development or lap splice lengths (i.e., shaded areas) should be avoided if at all possible for the larger bar sizes. These inordinately long lengths present possible constructability problems due to placing, congestion, etc. Options available in trying to avoid Category 1 or 2 conditions include:
   (a) Increasing the concrete cover to more than one bar diameter and/or increasing the bar c.-c. spacing to more than three bar diameters.
   (b) Utilizing the A_v allowance in ACI 12.2.3.1(b) for beams or columns. Note that if ties or stirrups meet the minimum A_v requirement, Category 1 lengths are reduced to Category 5 lengths and Category 2 lengths are reduced to Category 6 lengths.

One additional note applies to the tabulated values of tension lap splice lengths in Tables 5(a) through 5(f) and Tables 7(a) through 7(f):

1. Lap splice lengths are multiples of tension ℓ_d, i.e., values in Table 5(a) are multiples of ℓ_d in Table 4(a); values in Table 7(a) are multiples of ℓ_d in Table 6(a); etc.; Class A= 1.0 ℓ_d and Class B= 1.3 ℓ_d (ACI 12.15.1).

One additional note applies to the tabulated values of tension development and lap splice lengths for epoxy-coated bars in Tables 6(a) through 6(f) and Tables 7(a) through 7(f):

1. If c.-c. spacing is at least 7 d_b and concrete cover is at least 3 d_b, then Category 6 lengths may be multiplied by 0.918 (top bars) or by 0.8 (other bars).

TABLE 4(a)—Tension Development Lengths, ℓ_d (inches) for Grade 60 Uncoated Bars
f'_c= 3000 psi; Normal Weight Concrete

BAR SIZE	TOP BARS Category 1	2	3	4	5	6	OTHER BARS Category 1	2	3	4	5	6
#3	16	16	16	16	16	16	13	13	13	13	13	13
#4	23	22	22	22	22	22	18	17	17	17	17	17
#5	36	29	27	27	27	27	27	22	21	21	21	21
#6	50	40	35	32	32	32	39	31	27	25	25	25
#7	69	55	48	39	38	38	53	42	37	30	29	29
#8	90	72	63	51	45	43	70	56	49	39	35	33
#9	114	91	80	64	57	48	88	70	62	49	44	37
#10	145	116	102	81	73	58	112	89	78	63	56	45
#11	178	142	125	100	89	71	137	110	96	77	69	55
#14	242	242	170	170	121	121	187	187	131	131	93	93
#18	356	356	250	250	178	178	274	274	192	192	137	137

TABLE 4(b)—Tension Development Lengths, ℓ_d (inches) for Grade 60 Uncoated Bars
f'_c= 4000 psi; Normal Weight Concrete

BAR SIZE	TOP BARS Category 1	2	3	4	5	6	OTHER BARS Category 1	2	3	4	5	6
#3	14	14	14	14	14	14	12	12	12	12	12	12
#4	20	19	19	19	19	19	15	15	15	15	15	15
#5	31	25	23	23	23	23	24	19	18	18	18	18
#6	44	35	31	28	28	28	34	27	24	22	22	22
#7	59	48	42	33	33	33	46	37	32	26	25	25
#8	78	63	55	44	39	37	60	48	42	34	30	29
#9	99	79	69	56	50	42	76	61	53	43	38	32
#10	126	101	88	70	63	50	97	77	68	54	48	39
#11	154	123	108	86	77	62	119	95	83	67	59	48
#14	210	210	147	147	105	105	162	162	113	113	81	81
#18	309	309	216	216	154	154	237	237	166	166	119	119

TABLE 4(c)—Tension Development Lengths, ℓ_d (inches) for Grade 60 Uncoated Bars
f'_c= 5000 psi; Normal Weight Concrete

BAR SIZE	TOP BARS Category 1	2	3	4	5	6	OTHER BARS Category 1	2	3	4	5	6
#3	13	13	13	13	13	13	12	12	12	12	12	12
#4	18	17	17	17	17	17	14	13	13	13	13	13
#5	28	22	21	21	21	21	21	17	16	16	16	16
#6	39	31	27	25	25	25	30	24	21	19	19	19
#7	53	43	37	30	29	29	41	33	29	23	23	23
#8	70	56	49	39	35	33	54	43	38	30	27	26
#9	89	71	62	50	44	38	68	55	48	38	34	29
#10	112	90	79	63	56	45	87	69	61	49	43	35
#11	138	110	97	77	69	55	106	85	74	60	53	43
#14	188	188	132	132	94	94	145	145	101	101	72	72
#18	276	276	193	193	138	138	212	212	149	149	106	106

TABLE 4(d)—Tension Development Lengths, ℓ_d (inches) for Grade 60 Uncoated Bars
f'_c= 6000 psi; Normal Weight Concrete

BAR SIZE	TOP BARS Category 1	2	3	4	5	6	OTHER BARS Category 1	2	3	4	5	6
#3	12	12	12	12	12	12	12	12	12	12	12	12
#4	16	15	15	15	15	15	13	12	12	12	12	12
#5	25	20	19	19	19	19	20	16	15	15	15	15
#6	36	29	25	23	23	23	28	22	19	18	18	18
#7	49	39	34	27	27	27	37	30	26	21	21	21
#8	64	51	45	36	32	31	49	39	35	28	25	24
#9	81	65	57	45	41	34	62	50	44	35	31	27
#10	103	82	72	58	51	41	79	63	55	44	40	32
#11	126	101	88	71	63	51	97	78	68	54	49	39
#14	171	171	120	120	86	86	132	132	92	92	66	66
#18	252	252	177	177	126	126	194	194	136	136	97	97

TABLE 4(e)—Tension Development Lengths, ℓ_d (inches) for Grade 60 Uncoated Bars
f'_c=7000 psi; Normal Weight Concrete

BAR SIZE	TOP BARS Category 1	2	3	4	5	6	OTHER BARS Category 1	2	3	4	5	6
#3	12	12	12	12	12	12	12	12	12	12	12	12
#4	15	14	14	14	14	14	12	12	12	12	12	12
#5	23	19	18	18	18	18	18	15	14	14	14	14
#6	33	27	23	21	21	21	26	20	18	16	16	16
#7	45	36	32	25	25	25	35	28	24	20	19	19
#8	59	47	42	33	30	28	46	37	32	26	23	22
#9	75	60	53	42	38	32	58	46	40	32	29	25
#10	95	76	67	53	48	38	73	59	51	41	37	29
#11	117	93	82	65	58	47	90	72	63	50	45	36
#14	159	159	111	111	80	80	122	122	86	86	61	61
#18	233	233	163	163	117	117	180	180	126	126	90	90

TABLE 4(f)—Tension Development Lengths, ℓ_d (inches) for Grade 60 Uncoated Bars
f'_c= 8000 psi; Normal Weight Concrete

BAR SIZE	TOP BARS Category 1	2	3	4	5	6	OTHER BARS Category 1	2	3	4	5	6
#3	12	12	12	12	12	12	12	12	12	12	12	12
#4	14	13	13	13	13	13	12	12	12	12	12	12
#5	22	18	17	17	17	17	17	14	13	13	13	13
#6	31	25	22	20	20	20	24	19	17	15	15	15
#7	42	34	30	24	23	23	32	26	23	18	18	18
#8	55	44	39	31	28	269	43	34	30	24	21	20
#9	70	56	49	39	35	30	54	43	38	30	27	23
#10	89	71	62	50	45	36	68	55	48	38	34	28
#11	109	87	76	61	55	44	84	67	59	47	42	34
#14	149	149	1041	104	74	74	1141	114	80	80	57	57
#18	218	218	93	153	109	109	68	168	118	118	84	84

TABLE 5(a)—Tension Lap Splices Lengths (inches) for Grade 60 Uncoated Bars f'_c= 3000 psi; Normal Weight Concrete

Bar Size	Lap Class	TOP BARS						OTHER BARS					
		Category						Category					
		1	2	3	4	5	6	1	2	3	4	5	6
#3	A	16	16	16	16	16	16	13	13	13	13	13	13
	B	21	21	21	21	21	21	16	16	16	16	16	16
#4	A	23	22	22	22	22	22	18	17	17	17	17	17
	B	30	28	28	28	28	28	23	22	22	22	22	22
#5	A	36	29	27	27	27	27	27	22	21	21	21	21
	B	46	37	35	35	35	35	36	29	27	27	27	27
#6	A	50	40	35	32	32	32	39	31	27	25	25	25
	B	65	52	46	42	42	42	50	40	35	32	32	32
#7	A	69	55	48	39	38	38	53	42	37	30	29	29
	B	89	71	63	50	49	49	69	55	48	39	38	38
#8	A	90	72	63	51	45	43	70	56	49	39	35	33
	B	117	94	82	66	59	56	90	72	63	51	45	43
#9	A	114	91	80	64	57	48	88	70	62	49	44	37
	B	148	119	104	83	74	63	114	91	80	64	57	48
#10	A	145	116	102	81	73	58	112	89	78	63	56	45
	B	188	151	132	106	94	76	145	116	102	81	73	58
#11	A	178	142	125	100	89	71	137	110	96	77	69	55
	B	231	185	162	130	116	93	178	142	125	100	89	71

TABLE 5(b)—Tension Lap Splices Lengths (inches) for Grade 60 Uncoated Bars f'_c= 4000 psi; Normal Weight Concrete

Bar Size	Lap Class	TOP BARS						OTHER BARS					
		Category						Category					
		1	2	3	4	5	6	1	2	3	4	5	6
#3	A	14	14	14	14	14	14	12	12	12	12	12	12
	B	18	18	18	18	18	18	16	16	16	16	16	16
#4	A	20	19	19	19	19	19	15	15	15	15	15	15
	B	26	24	24	24	24	24	20	19	19	19	19	19
#5	A	31	25	23	23	23	23	24	19	18	18	18	18
	B	40	32	30	30	30	30	31	25	23	23	23	23
#6	A	44	35	31	28	28	28	34	27	24	22	22	22
	B	57	45	40	36	36	36	44	35	31	28	28	28
#7	A	59	48	42	33	33	33	46	37	32	26	25	25
	B	77	62	54	43	42	42	59	48	42	33	33	33
#8	A	78	63	55	44	39	37	60	48	42	34	30	29
	B	102	81	71	57	51	48	78	63	55	44	39	37
#9	A	99	79	69	56	50	42	76	61	53	43	38	32
	B	129	103	90	72	64	55	99	79	69	56	50	42
#10	A	126	101	88	70	63	50	97	77	68	54	48	39
	B	163	131	114	92	82	65	126	101	88	70	63	50
#11	A	154	123	108	86	77	62	119	95	83	67	59	48
	B	200	160	140	112	100	80	154	123	108	86	77	62

TABLE 5(c)—Tension Lap Splices Lengths (inches) for Grade 60 Uncoated Bars f'_c= 5000 psi; Normal Weight Concrete

Bar Size	Lap Class	TOP BARS						OTHER BARS					
		Category						Category					
		1	2	3	4	5	6	1	2	3	4	5	6
#3	A	13	13	13	13	13	13	12	12	12	12	12	12
	B	16	16	16	16	16	16	16	16	16	16	16	16
#4	A	18	17	17	17	17	17	14	13	13	13	13	13
	B	23	22	22	22	22	22	18	17	17	17	17	17
#5	A	28	22	21	21	21	21	21	17	16	16	16	16
	B	36	29	27	27	27	27	28	22	21	21	21	21
#6	A	39	31	27	27	25	25	30	24	21	19	19	19
	B	51	41	36	36	33	33	39	31	27	25	25	25
#7	A	53	43	37	37	29	29	41	33	29	23	23	23
	B	69	55	48	48	38	38	53	43	37	30	29	29
#8	A	70	56	49	49	35	33	54	43	38	30	27	26
	B	91	73	64	64	46	43	70	56	49	39	35	33
#9	A	89	71	62	62	44	38	68	55	48	38	34	29
	B	115	92	81	81	58	49	89	71	62	50	44	38
#10	A	112	90	79	79	56	45	87	69	61	49	43	35
	B	146	117	102	102	73	59	112	90	79	63	56	45
#11	A	138	110	97	97	69	55	106	85	74	60	53	43
	B	179	143	126	126	90	72	138	110	97	77	69	55

TABLE 5(d)—Tension Lap Splices Lengths (inches) for Grade 60 Uncoated Bars f'_c= 6000 psi; Normal Weight Concrete

Bar Size	Lap Class	TOP BARS						OTHER BARS					
		Category						Category					
		1	2	3	4	5	6	1	2	3	4	5	6
#3	A	12	12	12	12	12	12	12	12	12	12	12	12
	B	16	16	16	16	16	16	16	16	16	16	16	16
#4	A	16	15	15	15	15	15	13	12	12	12	12	12
	B	21	20	20	20	20	20	16	16	16	16	16	16
#5	A	25	20	19	19	19	19	20	15	15	15	15	15
	B	33	26	25	25	25	25	25	20	19	19	19	19
#6	A	36	29	25	23	23	23	28	22	19	18	18	18
	B	46	37	33	30	30	30	36	29	25	23	23	23
#7	A	49	39	34	27	27	27	37	30	35	21	21	21
	B	63	51	44	35	35	35	49	39	45	27	27	27
#8	A	64	51	45	36	32	31	49	39	35	28	25	24
	B	83	66	58	47	42	40	64	51	45	36	32	31
#9	A	81	65	57	45	41	34	62	50	44	35	31	27
	B	105	84	74	59	53	45	81	65	57	45	41	34
#10	A	103	82	72	58	51	41	79	63	55	44	40	32
	B	133	107	93	75	67	54	103	82	72	58	51	41
#11	A	126	101	88	71	63	51	97	78	68	54	49	39
	B	164	131	115	92	82	66	126	101	88	71	63	51

TABLE 5(e)—Tension Lap Splices Lengths (inches) for Grade 60 Uncoated Bars f'_c=7000 psi; Normal Weight Concrete

Bar Size	Lap Class	TOP BARS						OTHER BARS					
		Category						Category					
		1	2	3	4	5	6	1	2	3	4	5	6
#3	A	12	12	12	12	12	12	12	12	12	12	12	12
	B	16	16	16	16	16	16	16	16	16	16	16	16
#4	A	15	14	14	14	14	14	12	12	12	12	12	12
	B	20	18	18	18	18	18	16	16	16	16	16	16
#5	A	23	19	18	18	18	18	18	15	14	14	14	14
	B	30	24	23	23	23	23	23	19	18	18	18	18
#6	A	33	27	23	21	21	21	26	20	18	16	16	16
	B	43	34	30	28	28	28	33	27	23	21	21	21
#7	A	45	36	32	25	25	25	35	28	24	20	19	19
	B	58	47	41	33	32	32	45	36	32	25	25	25
#8	A	59	47	42	33	30	28	46	37	32	26	23	22
	B	77	62	54	43	39	37	59	47	42	33	30	28
#9	A	75	60	53	42	38	32	58	46	40	32	29	25
	B	97	78	68	55	49	41	75	60	53	42	38	32
#10	A	95	76	67	53	48	38	73	59	51	41	37	29
	B	123	99	86	69	62	50	95	76	67	53	48	38
#11	A	117	93	82	65	58	47	90	72	63	50	45	36
	B	152	121	106	85	76	61	117	93	82	65	58	47

TABLE 5(f)—Tension Lap Splices Lengths (inches) for Grade 60 Uncoated Bars f'_c= 8000 psi; Normal Weight Concrete

Bar Size	Lap Class	TOP BARS						OTHER BARS					
		Category						OTHER BARS					
		1	2	3	4	5	6	1	2	3	4	5	6
#3	A	12	12	12	12	12	12	12	12	12	12	12	12
	B	16	16	16	16	16	16	16	16	16	16	16	16
#4	A	14	13	13	13	13	13	12	12	12	12	12	12
	B	18	17	17	17	17	17	16	16	16	16	16	16
#5	A	22	18	17	17	17	17	17	14	13	13	13	13
	B	28	23	22	22	22	22	22	18	17	17	17	17
#6	A	31	25	22	20	20	20	24	19	17	15	15	15
	B	40	32	28	26	26	26	31	25	22	20	20	20
#7	A	42	34	30	24	23	23	32	26	23	18	18	18
	B	55	44	38	31	30	30	42	34	30	24	23	23
#8	A	55	44	39	31	28	26	43	34	30	24	21	20
	B	72	58	50	40	36	34	55	44	39	31	28	26
#9	A	70	56	49	39	35	30	54	43	38	30	27	23
	B	91	73	64	51	46	39	70	56	49	39	35	30
#10	A	89	71	62	50	45	36	68	55	48	38	34	28
	B	115	92	81	65	58	46	89	71	62	50	45	36
#11	A	109	87	76	61	55	44	84	67	59	47	42	34
	B	142	113	99	80	71	57	109	87	76	61	55	44

APPENDIX B—ACI 318-89 Tension Development and Lap Splice Tables

TABLE 6(a)—Tension Development Lengths, ℓ_d (inches) for Grade 60 Epoxy-Coated Bars
f'_c = 3000 psi; Normal Weight Concrete

BAR SIZE	TOP BARS						OTHER BARS					
	Category						Category					
	1	2	3	4	5	6	1	2	3	4	5	6
#3	21	21	21	21	21	21	19	19	19	19	19	19
#4	30	28	28	28	28	28	27	25	25	25	25	25
#5	46	37	35	35	35	35	41	33	31	31	31	31
#6	66	53	46	42	42	42	58	47	41	37	37	37
#7	90	72	63	50	49	49	79	63	56	44	43	43
#8	118	94	83	66	59	56	104	83	73	58	52	50
#9	149	119	105	84	75	63	132	105	92	74	66	56
#10	190	152	133	106	95	76	167	134	117	94	84	67
#11	233	186	163	130	117	93	205	164	144	115	103	82
#14	317	317	222	222	159	159	280	280	196	196	140	140
#18	466	466	326	326	233	233	411	411	288	288	206	206

TABLE 6(b)—Tension Development Lengths, ℓ_d (inches) for Grade 60 Epoxy-Coated Bars
f'_c = 4000 psi; Normal Weight Concrete

BAR SIZE	TOP BARS						OTHER BARS					
	Category						Category					
	1	2	3	4	5	6	1	2	3	4	5	6
#3	18	18	18	18	18	18	16	16	16	16	16	16
#4	26	24	24	24	24	24	23	22	22	22	22	22
#5	40	32	31	31	31	31	36	29	27	27	27	27
#6	57	46	40	37	37	37	50	40	35	32	32	32
#7	78	62	54	44	43	43	69	55	48	39	38	38
#8	102	82	72	57	51	49	90	72	63	51	45	43
#9	129	104	91	73	65	55	114	91	80	64	57	48
#10	164	131	115	92	82	66	145	116	102	81	73	58
#11	202	161	141	113	101	81	178	142	125	100	89	71
#14	274	274	192	192	137	137	242	242	170	170	121	121
#18	403	403	283	283	202	202	356	356	249	249	178	178

TABLE 6(c)—Tension Development Lengths, ℓ_d (inches) for Grade 60 Epoxy-Coated Bars
f'_c = 5000 psi; Normal Weight Concrete

BAR SIZE	TOP BARS						OTHER BARS					
	Category						Category					
	1	2	3	4	5	6	1	2	3	4	5	6
#3	17	17	17	17	17	17	15	15	15	15	15	15
#4	23	22	22	22	22	22	21	19	19	19	19	19
#5	36	29	27	27	27	27	32	26	24	24	24	24
#6	51	41	36	33	33	33	45	36	32	29	29	29
#7	70	56	49	39	38	38	61	49	43	35	34	34
#8	91	73	64	51	46	44	81	65	57	45	41	38
#9	116	93	81	65	58	49	102	82	72	57	51	43
#10	147	118	103	82	74	59	130	104	91	73	65	52
#11	180	144	126	101	90	72	159	127	111	89	80	64
#14	246	246	172	172	123	123	217	217	152	152	108	108
#18	361	361	253	253	181	181	318	318	223	223	159	159

TABLE 6(d)—Tension Development Lengths, ℓ_d (inches) for Grade 60 Epoxy-Coated Bars
f'_c = 6000 psi; Normal Weight Concrete

BAR SIZE	TOP BARS						OTHER BARS					
	Category						Category					
	1	2	3	4	5	6	1	2	3	4	5	6
#3	15	15	15	15	15	15	13	13	13	13	13	13
#4	21	20	20	20	20	20	19	18	18	18	18	18
#5	33	26	25	25	25	25	29	23	22	22	22	22
#6	47	37	33	30	30	30	41	33	29	26	26	26
#7	64	51	45	36	35	35	56	45	39	32	31	31
#8	84	67	59	47	42	40	74	59	52	41	37	35
#9	106	85	74	59	53	45	93	75	65	52	47	40
#10	134	107	94	75	67	54	118	95	83	66	59	48
#11	165	132	115	92	82	66	145	116	102	82	73	58
#14	224	224	157	157	112	112	198	198	139	139	99	99
#18	330	330	231	231	165	165	291	291	204	204	146	146

TABLE 6(e)—Tension Development Lengths, ℓ_d (inches) for Grade 60 Epoxy-Coated Bars
f'_c = 7000 psi; Normal Weight Concrete

BAR SIZE	TOP BARS						OTHER BARS					
	Category						Category					
	1	2	3	4	5	6	1	2	3	4	5	6
#3	14	14	14	14	14	14	12	12	12	12	12	12
#4	20	19	19	19	19	19	18	16	16	16	16	16
#5	31	24	23	23	23	23	27	22	20	20	20	20
#6	43	35	30	28	28	28	38	31	27	25	25	25
#7	59	47	41	33	32	32	52	42	36	29	29	29
#8	77	62	54	43	39	37	68	55	48	38	34	33
#9	98	78	69	55	49	42	86	69	61	48	43	37
#10	124	99	87	70	62	50	110	88	77	62	55	44
#11	152	122	107	86	76	61	135	108	94	75	67	54
#14	208	208	145	145	104	104	183	183	128	128	92	92
#18	305	305	214	214	153	153	269	269	189	189	135	135

TABLE 6(f)—Tension Development Lengths, ℓ_d (inches) for Grade 60 Epoxy-Coated Bars
f'_c = 8000 psi; Normal Weight Concrete

BAR SIZE	TOP BARS						OTHER BARS					
	Category						Category					
	1	2	3	4	5	6	1	2	3	4	5	6
#3	13	13	13	13	13	13	12	12	12	12	12	12
#4	19	17	17	17	17	17	16	15	15	15	15	15
#5	29	23	22	22	22	22	25	20	19	19	19	19
#6	40	32	28	26	26	26	36	29	25	23	23	23
#7	55	44	39	31	30	30	49	39	34	27	27	27
#8	72	58	51	41	36	35	64	51	45	36	32	30
#9	92	73	64	51	46	39	81	65	57	45	41	34
#10	116	93	81	65	58	47	103	82	72	58	51	41
#11	143	114	100	80	71	57	126	101	88	71	63	51
#14	194	194	136	136	97	97	171	171	120	120	86	86
#18	285	285	200	200	143	143	252	252	176	176	126	126

TABLE 7(a)—Tension Lap Splice Lengths (inches) for Grade 60 Uncoated Bars f'_c= 3000 psi; Normal Weight Concrete

Bar Size	Lap Class	TOP BARS Category						OTHER BARS Category					
		1	2	3	4	5	6	1	2	3	4	5	6
#3	A	21	21	21	21	21	21	19	19	19	19	19	19
	B	28	28	28	28	28	28	24	24	24	24	24	24
#4	A	30	28	28	28	28	28	27	25	25	25	25	25
	B	39	37	37	37	37	37	34	32	32	32	32	32
#5	A	46	37	35	35	35	35	41	33	31	31	31	31
	B	60	48	46	46	46	46	53	43	40	40	40	40
#6	A	66	53	46	42	42	42	58	47	41	37	37	37
	B	86	68	60	55	55	55	75	60	53	48	48	48
#7	A	90	72	63	50	49	49	79	63	56	44	43	43
	B	117	93	82	65	64	64	103	82	72	58	56	56
#8	A	118	94	83	66	59	56	104	83	73	58	52	50
	B	153	123	107	86	77	73	135	108	95	76	68	64
#9	A	149	119	105	84	75	63	132	105	92	74	66	56
	B	194	155	136	109	97	82	171	137	120	96	86	73
#10	A	190	152	133	106	95	76	167	134	117	94	84	67
	B	246	197	172	138	123	99	217	174	152	122	109	87
#11	A	233	186	163	130	117	93	205	164	144	115	103	82
	B	302	242	212	169	151	121	267	214	187	150	134	107

TABLE 7(b)—Tension Lap Splice Lengths (inches) for Grade 60 Uncoated Bars f'_c= 4000 psi; Normal Weight Concrete

Bar Size	Lap Class	TOP BARS Category						OTHER BARS Category					
		1	2	3	4	5	6	1	2	3	4	5	6
#3	A	18	18	18	18	18	18	16	16	16	16	16	16
	B	24	24	24	24	24	24	21	21	21	21	21	21
#4	A	26	24	24	24	24	24	23	22	22	22	22	22
	B	34	32	32	32	32	32	30	28	28	28	28	28
#5	A	40	32	31	31	31	31	36	29	27	27	27	27
	B	52	42	40	40	40	40	46	37	35	35	35	35
#6	A	57	46	40	37	37	37	50	40	35	32	32	32
	B	74	59	52	47	47	47	65	52	46	42	42	42
#7	A	78	62	54	44	43	43	69	55	48	39	38	38
	B	101	81	71	57	55	55	89	71	62	50	49	49
#8	A	102	82	72	57	51	49	90	72	63	51	45	43
	B	133	106	93	75	67	63	117	94	82	66	59	56
#9	A	129	104	91	73	65	55	114	91	80	64	57	48
	B	168	134	118	94	84	71	148	119	104	83	74	63
#10	A	164	131	115	92	82	66	145	116	102	81	73	58
	B	213	171	149	120	107	86	188	151	132	106	94	75
#11	A	202	161	141	113	101	81	478	142	125	100	89	71
	B	262	210	183	147	131	105	231	185	162	130	116	93

TABLE 7(c)—Tension Lap Splice Lengths (inches) for Grade 60 Uncoated Bars f'_c= 5000 psi; Normal Weight Concrete

Bar Size	Lap Class	TOP BARS Category						OTHER BARS Category					
		1	2	3	4	5	6	1	2	3	4	5	6
#3	A	17	17	17	17	17	17	15	15	15	15	15	15
	B	21	21	21	21	21	21	19	19	19	19	19	19
#4	A	23	22	22	22	22	22	21	19	19	19	19	19
	B	30	28	28	28	28	28	27	25	25	25	25	25
#5	A	36	29	27	27	27	27	32	26	24	24	24	24
	B	47	38	35	35	35	35	41	33	31	31	31	31
#6	A	51	41	36	33	33	33	45	36	32	29	29	29
	B	66	53	47	42	42	42	59	47	41	38	38	38
#7	A	70	56	49	39	38	38	61	49	43	35	34	34
	B	90	72	63	51	50	50	80	64	56	45	44	44
#8	A	91	73	64	51	46	44	81	65	57	45	41	38
	B	119	95	83	67	60	57	105	84	74	59	53	50
#9	A	116	93	81	65	58	49	102	82	72	57	51	43
	B	150	120	105	84	75	64	133	106	93	74	66	56
#10	A	147	118	103	82	74	59	130	104	91	73	65	52
	B	191	153	134	107	96	77	168	135	118	94	84	68
#11	A	180	144	126	101	90	72	159	127	111	89	80	64
	B	234	188	164	131	117	94	207	165	145	116	104	83

TABLE 7(d)—Tension Lap Splice Lengths (inches) for Grade 60 Uncoated Bars f'_c= 6000 psi; Normal Weight Concrete

Bar Size	Lap Class	TOP BARS Category						OTHER BARS Category					
		1	2	3	4	5	6	1	2	3	4	5	6
#3	A	15	15	15	15	15	15	13	13	13	13	13	13
	B	20	20	20	20	20	20	17	17	17	17	17	17
#4	A	21	20	20	20	20	20	19	18	18	18	18	18
	B	28	26	26	26	26	26	24	23	23	23	23	23
#5	A	33	26	25	25	25	25	29	23	22	22	22	22
	B	43	34	32	32	32	32	38	30	29	29	29	29
#6	A	47	37	33	30	30	30	41	33	29	26	26	26
	B	61	49	42	39	39	39	53	43	38	34	34	34
#7	A	64	51	45	36	35	35	56	45	39	32	31	31
	B	82	66	58	46	45	45	73	58	51	41	40	40
#8	A	84	67	59	47	42	40	74	59	52	41	37	35
	B	108	87	76	61	54	52	96	77	67	54	48	46
#9	A	106	85	74	59	53	45	93	75	65	52	47	40
	B	137	110	96	77	69	58	121	97	85	68	61	51
#10	A	134	107	94	75	67	54	118	95	83	66	59	48
	B	174	139	122	98	87	70	154	123	108	86	77	62
#11	A	165	132	115	92	82	66	145	116	102	82	73	58
	B	214	171	150	120	107	86	189	151	132	106	95	76

TABLE 7(e)—Tension Lap Splice Lengths (inches) for Grade 60 Uncoated Bars f'_c=7000 psi; Normal Weight Concrete

Bar Size	Lap Class	TOP BARS Category						OTHER BARS Category					
		1	2	3	4	5	6	1	2	3	4	5	6
#3	A	14	14	14	14	14	14	12	12	12	12	12	12
	B	18	18	18	18	18	18	16	16	16	16	16	16
#4	A	20	19	19	19	19	19	18	16	16	16	16	16
	B	26	24	24	24	24	24	23	21	21	21	21	21
#5	A	31	24	23	23	23	23	27	22	20	20	20	20
	B	40	32	30	30	30	30	35	28	27	27	27	27
#6	A	43	35	30	28	28	28	38	31	27	25	25	25
	B	56	45	39	36	36	36	50	40	358	32	32	32
#7	A	59	47	41	33	32	32	52	42	36	29	29	29
	B	76	61	54	43	42	42	67	54	47	38	37	37
#8	A	77	62	54	43	39	37	68	55	48	38	34	33
	B	100	80	70	56	50	48	89	71	62	50	44	42
#9	A	98	78	69	55	49	42	86	69	61	48	43	37
	B	127	102	89	71	64	54	112	90	79	63	56	48
#10	A	124	99	87	70	62	50	110	88	77	62	55	44
	B	161	129	113	90	81	65	142	114	100	80	71	57
#11	A	152	122	107	86	76	61	135	108	94	75	67	54
	B	198	159	139	111	99	79	175	140	122	98	88	70

TABLE 7(f)—Tension Lap Splice Lengths (inches) for Grade 60 Uncoated Bars f'_c= 8000 psi; Normal Weight Concrete

Bar Size	Lap Class	TOP BARS Category						OTHER BARS Category					
		1	2	3	4	5	6	1	2	3	4	5	6
#3	A	13	13	13	13	13	13	12	12	12	12	12	12
	B	17	17	17	17	17	17	16	16	16	16	16	16
#4	A	19	17	17	17	17	17	16	15	15	15	15	15
	B	24	23	23	23	23	23	21	20	20	20	20	20
#5	A	29	23	22	22	22	22	25	20	19	19	19	19
	B	37	30	28	28	28	28	33	26	25	25	25	25
#6	A	40	32	28	26	26	26	36	29	25	23	23	23
	B	52	42	37	34	34	34	46	37	33	30	30	30
#7	A	55	44	39	31	30	30	49	39	34	27	27	27
	B	71	57	50	40	39	39	63	51	44	35	35	3[illegible]
#8	A	72	58	51	41	36	35	64	51	45	36	32	3[illegible]
	B	94	75	66	53	47	45	83	66	58	47	42	4[illegible]
#9	A	92	73	64	51	46	39	81	65	57	45	41	3[illegible]
	B	119	95	83	67	60	50	105	84	74	59	53	4[illegible]
#10	A	116	93	81	65	58	47	103	82	72	58	51	4[illegible]
	B	151	121	106	85	76	61	133	107	93	75	67	5[illegible]
#11	A	143	114	100	80	71	57	126	101	88	71	63	5[illegible]
	B	185	148	130	104	93	74	164	131	115	92	82	6[illegible]

APPENDIX C—Mechanical Splice Manufacturers

Bar-Lock Coupler Systems (Bar-Lock)
P. O. Box 28280
Bellingham, WA 98228
Tel: 360-738-1891
Fax: 360-738-1887

BarSplice Products, Inc. (BarSplice)
1300 Granger Hall Road
Beavercreek, OH 45430
Tel: 937-427-6466
Fax: 937-427-6470

Dayton Superior Corporation (Dayton)
721 Richard Street
Miamisburg, OH 45342
Tel: 513-866-0711
Fax: 513-866-1558

Dywidag Systems International, USA, Inc. (DSI)
107 Beaver Brook Road
Lincoln Park, NJ 07035
Tel: 201-628-8700
Fax: 201-628-8253

Erico, Inc. (Erico)
34600 Solon Road
Cleveland, OH 44139
Tel: 216-248-0100
Fax: 216-349-3163

Fox-Howlett Industries, Inc. (Fox-Howlett)
744 Folger Avenue
Berkeley, CA 94710
Tel: 510-841-1016
Fax: 510-841-1018

Harris Rebar, Inc. (Harris)
P. O. Box 9990
Stoney Creek, Ontario, CANADA L8G 3Y4
Tel: 905-662-5700
Fax: 905-561-7326

Headed Reinforcement Corp. (HRC)
11200 Condor Avenue
Fountain Valley, CA 92708
Tel: 714-557-1455
Fax: 714-557-4460

Richmond Screw Anchor Co., Inc. (Richmond)
7214 Burns Street
Richland Hills
Ft. Worth, TX 76118
Tel: 817-284-4981
Fax: 817-284-4504

Splice Sleeve North America (SSNA)
18 Scott Road
Harvard, MA 01451
Tel: 508-456-8085
Fax: 508-456-8191

Mechanical Splice	Splice Manufacturer									
	Bar-Lock	BarSplice	Dayton	DSI	Erico	Fox-Howlett	Harris	HRC	Richmond	SSNA
Tension-Compression Mechanical Splice										
Cold-Swaged Coupling Sleeve		X							X	
Cold-Swaged Threaded Coupling		X								
Combination Grout-Filled/Threaded Sleeve					X				X	
Coupler for Thread-Deformed Rebar				X						
Coupling Sleeve with Wedge					X					X
Extruded Coupling Sleeve				X						
Grout-Filled Coupling Sleeve										X
Hot-Forged Coupling Sleeve							X			
Shear Bolt Coupling Sleeve	X	X								
Steel-Filled Coupling Sleeve					X					
Straight Thread Coupler with Upset Rebar Ends								X		
Taper-Threaded Coupler					X	X		X		
Upset Straight Thread Coupler			X					X	X	
Non-Upset Straight Thread Coupler		X	X						X	
Compression-Only Mechanical Splice										
Bolted Strap Coupling Sleeve					X		X			
Steel-Filled Coupling Sleeve					X					
Wedge-Locking Coupling Sleeve		X								